University of Kent

School of Economics

MPhil Thesis: Studying and comparing the factors and the methodologies for the adoption of ecological farming technologies

Theodoros Tsiakalos

email: tt311@kent.ac.uk

Student ID: 18906893

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Abstract

This thesis is a literature review and the research question that tries to answer is: *How can the adoption of ecological agricultural technologies be studied?* The contribution of this thesis is to provide information regarding the adoption factors and the methodologies used to study the adoption of ecological farming technologies.

In chapter 1 we present the most cited articles in three databases (Google Scholar, Scopus and Web of Science) regarding the factors farmers take into account in order to adopt ecological farming technologies. Our goal is to provide information about the most common factors which are taken into account for the adoption of ecological methods of farming.

In chapter 2 we present the theoretical models used for the adoption of farming technologies by psychologists. We also present the research methods used more extensively by economists (the Expected Utility Theory and Discrete Choice Experiments).

In Chapter 3 we introduce Discrete Choice Experiments. We present the strong and weak points as well as the advancements of DCE. In addition, we present Hybrid Choice Models, which are extension of Discrete Choice Models and can incorporate unobservable factors.

This thesis concludes with chapter 4, which signifies the adoption of ecological farming and the usefulness of Discrete Choice Experiments and Hybrid Choice Models methods.

Introduction

Increase numbers of people raise concerns about conventional methods of farming and how these can affect human health and the natural environment. The protection of natural resources and biodiversity in Europe are becoming more evident (Poux and Aubert, 2018). The European Land has high levels of productivity because of the use of chemical pesticides and fertilizers, but at the cost of the health of farmers and consumers. In addition, according to researches the biodiversity is threatened as well (Poux and Aubert, 2018).

According to Bowman and Zilberman (2013) farmers choose farming activities and technologies based on increasing their income, decreasing their financial and physical risk, decreasing labour requirements and are easy and enjoyable to be used. As a result of these, many constraints appear to have an impact on farmers' decision for the adoption of conventional or ecological farming techniques (e.g. financial constraints, policy constraints, input constraints) (Stoorvogel et al., 2004, cited on Bowman and Zilberman, 2013, p.18). The literature on the adoption of farming technologies informs us that many factors can have an impact on the decision of farmers. In addition to this, there is asymmetric information about the costs, the gains and the implementation of adopting new farming technologies which affect the attitude of farmers to use them (Chavas et al., 2010; Chavas and Kim, 2010, cited on Bowman and Zilberman, 2013, p.18).

There has also been a rise in the demand of ecological agricultural products, because consumers consider them healthier. In addition, people have become more interested in the protection of natural resources and biodiversity. This can be achieved by adopting sustainable farming methods. According to Gliessman, Engles and Krieger (1998) sustainable agriculture is the procedure that can:

- have the minimum negative impact on the environment
- preserve and restructure soil fertility , prevent soil erosion and keep the levels of the ecological health of the soil intact
- efficient use of the water
- depend on inputs from the agrosystem
- value and preserve the biological diversity in the wild and in the urban areas
- secure equal access to agricultural methods, knowledge and technologies and check the agricultural resources locally

Gliessman (2007) describes agroecology as "the science of applying ecological concepts and principles to the design and management of sustainable food systems". Agroecology is the study of ecological processes that affects agriculture and may refer to a science, movement or practice. It looks at the interaction between flora and fauna (including humans) within the environment. The purpose is to create sustainable and productive farms. By integrating ecological principles into agricultural systems, new methods may be found that could benefit the environment and the agricultural sector. As a result both the environment and the domestic economies can become sustainable.

Furthermore, the Food and Agriculture Organization of the United Nations (FAO, 2016) has developed 10 elements of Agroecology in order to provide directions to policy makers, practitioners and stakeholders in planning and implementing the transition from conventional methods to environmentally friendlier methods. The 10 elements are diversity, information (co-creation and sharing of knowledge), synergies, efficiency, recycling, resilience, human and social values, culture and food traditions, responsible governance, circular and solidarity economy.

Huge amounts of agricultural products can be produced thanks to the modern agricultural systems. Nonetheless, this huge production contributes to water scarcities, high levels of deforestation and greenhouse emissions. As a result, conventional technologies of farming contribute to high financial and environmental costs.

The estimation of the value of environmental goods and policies is very important for Economics, because it is necessary to value the impact of the human consumption and production on the natural environment. As a result of these concerns, this study intends to investigate barriers and incentives for farmers becoming involved in the principles of Agroecology and changing technology from conventional to ecological methods of farming.

1. Literature Review on the factors of adoption of Farming Technologies

1.1 Introduction

More and more people raise concerns about conventional methods of farming and both consumers and producers are thinking of transitioning to environmentally friendlier agricultural products. As a result, the adoption or change of farming technologies has been taken into account seriously by both researchers and policy makers. Although, there are many common factors that are taken into account by farmers and policy makers, the factors do not present a specific universal behaviour and for this purpose the studies for the adoption of farming technologies on regional level are significant (Knowler and Bradshaw, 2007).

Farming technologies include all kinds of improved techniques, which affect the growth of agricultural output (Jain, Arora and Raju, 2009). According to Loevinsohn et al. (2013, p.3) technology is defined as "the means and methods of producing goods and services, including methods of organization, as well as physical technique". Moreover, Loevinsohn et al. (2013, p.3) characterise technology as new, when it is new to a specific location or group of farmers, or demonstrates a new use of technology that is already used within a specific place or by a group of farmers. The purpose of technology is to improve a given situation or develop the status quo (Lavison, 2013, p.19). The work can be done easier with the use of technology, than with its absence, so technology saves time and labour (Bonabana-Wabbi, 2002). Additionally, Lavison (2013, p.19) states technology "is aimed at improving a given situation or changing the status quo to a more desirable level".

It is significant to define the technology adoption. However, defining technology adoption is complicated due to the variations of the adopted technologies (Mwangi and Kariuki, 2015). On the one hand, Feder, Just and Zilberman (1985) define adoption at the level of the individual farmer as the degree of use of a new technology in long-term equilibrium, when the farmer is fully aware about the new technology and its capacity. On the other hand, Loevinsohn et al. (2013) describe adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation. So, studying which factors contribute to the adoption of a farming technology is important, because the processes that lead to adoption technology can be understood. As a result, suitable policies can be planned and implemented based on the needs of each farming technology and farmer.

We desire to shed more light on the adoption of new farming technologies. The existence of no universal factor for the adoption of a new farming technology in the literature creates an interesting field of research. In this way more research can be conducted on regional level and compare the results for the implementation of future policies. Furthermore, if policy makers and developers of new technologies want to promote a new technology, they need to understand both the need and the ability of farmers to adopt technology (Mwangi and Kariuki, 2015). As a result policy makers can take into consideration the proper factors for the adoption of a new farming technology in every region and the social welfare can be optimized.

In the 1st chapter we present the most cited published articles on three data bases (Google Scholar, Scopus and Web of Science). Our goal is to inform the reader regarding the different and most common factors taken into account about the adoption of ecological methods of farming.

1.2 Previous Studies

This section includes a presentation of the most cited published articles found on three data bases (Google Scholar, Scopus and Web of Science) regarding the adoption of a new ecological farming technology. The databases searches were between 1980 and 2020, and the keywords used were ecological agricultural technologies, ecological farming technologies, and ecological methods of farming. The papers are presented in a chronological order, in an attempt to illustrate, through research interest, the progress of adopting ecological methods of farming. This presentation starts from the first chronologically most cited paper identified in the search Kebede, Gunjal and Coffin (1990) and concludes with the presentation of Paustian and Theuvsen (2017).

Kebede, Gunjal and Coffin (1990) examine the determinants for the adoption of three farming technologies single-ox, fertilizer and pesticide technologies. In particular, they use a logit model and a series of variables, some factors are common and some are not in the three agricultural methods, ten total common factors (Kebede, Gunjal and Coffin, 1990).

Moreover, D'souza, Cyphers and Phipps (1993) use a logit and a probit model to check which factors affect the adoption of Sustainable Agricultural Practices in Western Virginia. Especially, the dependent variable is adopter/non-adopter and the rest of the variables are also categorical/binary variables (D'souza, Cyphers and Phipps, 1993) .

Fujisaka (1994) studies the reasons for which farmers do not adopt sustainability-enhancing innovations at a high rate in Philippines. More specifically, this paper combines the observations from researchers and extension workers, who are occupied with the adoption of innovations that will lead to improved upland agroecosystems sustainability (Fujisaka, 1994). The researcher visits the field in 5 cases and discusses with the adopters and non-adopters and he studies some project documents regarding farming adoption (Fujisaka, 1994).

Later, Khanna and Zilberman (1997) structures a theoretical model of agricultural production taking into account the heterogeneity among farmers and they model the adoption decision of farmers. They assume farmers/micro-units choose the precision technology and level of input-use that maximizes their quasi-rents per unit asset by undertaking a two-stage decision-making process (Khanna and Zilberman, 1997). When farmers choose a farming technology, they tradeoff between the positive attributes of precision technology and fixed costs per unit asset (Khanna and Zilberman, 1997). Additionally, Khanna and Zilberman (1997) take into account some attributes for the heterogeneity based on the literature, which are the physical environment: Soil quality, topology, and weather, which also influence the choice of input application techniques. Moreover, empirical analysis for the San Joaquin Valley shows that modern irrigation technologies are more heavily adopted on steeply sloped fields with lower water retaining soils and with salinity problems (Dinar et al., 1992, cited on Khanna and Zilberman, 1997, p. 34). Nitrogen testing in Nebraska is adopted more frequently on irrigated fields with higher organic content and pH (Bosch et al., 1995, cited on Khanna and Zilberman, 1997, p.35). In addition, the size of the farm is correlated with the adoption of soil conservation techniques in a positive way (Nowak, 1987; Heffernan and Green, 1986, cited on Khanna and Zilberman, 1997, p. 34), IPM (Integral Pest Management) (Thomas et al., 1990, cited on Khanna and Zilberman, 1997, p.34) and modern irrigation (Dinar et al., 1992, cited on Khanna and Zilberman, 1997, p.34). This may happen because the owners of larger farms can hire professionals easier and have better access to financial tools, information and more contracts with extension agents and representatives of agribusinesses (Khanna and Zilberman, 1997). Another factor, which researchers take into consideration, is the ownership of the fixed assets (e.g. land or capital equipment) (Khanna and Zilberman, 1997). Finally, other factors taken into account for the adoption of precision technology are the age of farmers, the education and the discount rates (Khanna and Zilberman, 1997).

In the early 2000s, research continues to be conducted examining the adoption factors for ecological farming technologies. Adesina et al. (2000) use a logit model to find the factors that influence farmers in southwest of Cameroon to adopt and use of alley farming variants. More specifically, the dependent variable is the decision to adopt alley cropping technology and the set of vectors of explanatory variables related to adoption, (a) land tenurial rights held by the farmers on the food crop fields where alley cropping is used; (b) socioeconomic characteristics of farmers; and (c) village-specific characteristics (Adesina et al., 2000).

Additionally, Adesina and Chianu (2002) study the factors for adoption and adaptation of alley farming technology in Nigeria with the use of logit models. Further, Ajayi et al. (2003) examine the adoption of improved fallows in Zambia. This paper reviews previous studies and the analysis shows the technology adoption depends on a matrix of determinants, which are household characteristics, community level factors, socioeconomic constraints and incentives that farmers face, access to information, local institutional arrangements and macro-policies on agriculture (Ajayi et al., 2003). Also, Ajayi et al. (2003) construct a table with the factors for the adoption of improved fallows in eastern Zambia.

Moreover, Burton, Rigby and Young (2003) model the adoption of organic horticultural technology in the UK and spot which factors have an impact on the decision for the adoption of this farming technology. According to Burton, Rigby and Young (2003), there have been 2 main statistical methods to search the use of a new farming technology, the one is bivariate analysis at the farm level, with adoption measured at a point in time (adoption studies), the other is to model the cumulative adoption rate at the aggregate level (diffusion studies). The used method is Duration Analysis, as well adoption and diffusion components are taken into account (Burton, Rigby and Young, 2003). Especially, duration analysis allows for both cross sectional and time series data analysis (Burton, Rigby and Young, 2003). Further, duration analysis spots statistically the factors that have an impact on the length of a spell, here the adoption of organic horticultural technology (Burton, Rigby and Young, 2003). Burton, Rigby and Young (2003) use 3 models, which have no much difference among them in terms of their results, based on Akaike information criterion. Last but not least, in this study cross sectional data are used from a survey of 237 farms in the UK, comprising 86 organic farmers (the ‘adopters’) and 151 conventional farmers (the ‘non-adopters’) (Burton, Rigby and Young, 2003).

On the other hand, Daberkow and McBride (2003) use farm level survey data to study the impact of awareness on the decision to adopt Precision Adoption methods, so that the diffusion of the Precision Agricultural can be investigated more. Their method is a logit model with instrumental variable in order to deal with the endogeneity of the awareness, because awareness is pre-condition to adopt a new technology (Daberkow and McBride, 2003).

Moreover, Diederen, van Meijl and Wolters (2003) study the factors for the adoption of an innovation-farming method in the Netherlands in 1998. They use data from the Dutch Farm Accountancy Data Network (FADN) and divide the farmers into innovators (17), early adopters (27), late adopters (44) and non-adopters (777), out of a total of 865 observations in 1998 (Diederen, van Meijl and Wolters, 2003). Furthermore, the researchers use an ordered probit model in order to study in which category the farmer falls (Diederen, van Meijl and Wolters, 2003).

Later on, Jacobson et al. (2003) use categorical variables and Likert-type format to conduct their survey in Northern Florida. Their purpose is to describe 'the social structure, social participation, communication networks, barriers and benefits to adoption of bird-friendly farming practices of northern Florida's conventional and organic farmers' (Jacobson et al., 2003). In addition, they use non-parametric statistics to compare responses between organic and conventional farmers and to compare responses between organic and conventional farmers and compare the determinants that affect the attitude of farmers regarding pest management and bird conservation (Jacobson et al., 2003). In the end, their goal is to check which factors are statistically significant for bird conservation on organic and conventional farming (Jacobson et al., 2003).

Also, Lee (2005) conducts a review and focuses on the key factors for the adoption of sustainable agricultural methods in developing countries. Additionally, Pimentel et al. (2005) use the results from a 22-year-old experiment from the Rodale Institute Farming Systems Trial and compare organic and conventional grain-based farming methods. Further, Shi and Gill (2005) use a systematic dynamics model to study the potential long-term ecological, economic, institutional and social interactions of ecological agricultural development through a case study of Jinshan County in China.

Birol, Smale and Gyovai (2006) apply the choice experiment method to estimate the private benefits of farmers, which come from the four components of the agrobiodiversity found in Hungarian home gardens: richness of crop varieties and fruit trees; crop landraces; integrated crop and livestock production; and soil micro-organism diversity. This study has implications for sustaining agrobiodiversity in transitional economies (Birol, Smale and Gyovai, 2006). Especially, Birol, Smale and Gyovai (2006) use a conditional logit models with logarithmic and linear specifications and their data come from three Environmentally Sensitive Areas of Hungary (Devavanya, Orseg-Vend and Szatmar-Bereg). Nonetheless, they have issues with the violation of the Independence of Irrelevant Alternatives (IIA) property (Birol, Smale and Gyovai, 2006). Finally, attributes based on the estimations of the mixed logit model are statistically significant at 1% and 5% for all the three areas (Birol, Smale and Gyovai, 2006).

Genius, Pantzios and Tzouvelekas (2006) study the decision of farmers to adopt organic farming methods and getting informed for the technicalities of the various farming technologies. In fact, 237 farmers, who are located in Chania, Rethymno, Heraklio, and Lasithi in Crete during the 1996-97 period, are selected randomly (Genius, Pantzios and Tzouvelekas, 2006). The used method is a trivariate probit model, where the probability of adoption is affected by the way the information is obtained (Genius, Pantzios and Tzouvelekas, 2006). Consequently, Genius, Pantzios and Tzouvelekas (2006) present a trivariate choice model with one of the choices being ordered.

Later, Knowler and Bradshaw (2007) conduct a review about the universal factors for the adoption of conservation agriculture. More specifically, Knowler and Bradshaw (2007) use 31 previous studies to check the behaviour of 46 adoption factors. Some factors are statistically significant in some studies and in some others they are not (Knowler and Bradshaw, 2007). Additionally, only seven variables have consistent behaviour across all the studies in their review (always insignificant or always significant with the same sign), while just two, ‘awareness of environmental threats’ and ‘high productivity soil’ have a consistent influence on adoption (significant with same sign) (Knowler and Bradshaw, 2007). Furthermore, Knowler and Bradshaw (2007) mention the used scientific methods in their review (e.g. OLS, Probit models).

Additionally, McBride and Greene (2007) examine the costs and the returns of organic and conventional dairies. One of their aims is to find which factors motivate farmers to adopt organic methods (McBride and Greene, 2007). Specifically, McBride and Greene (2007) use data from a survey of U.S. dairy operations for 2005. As far as the methodology is concerned, McBride and Greene (2007) specify treatment-effect sample-selection models to isolate the influence of choosing organic method on different levels of milk production costs.

Next, Wheeler (2008) conducts a survey to check how increased knowledge and experience have an impact on attitudes towards organic agriculture. Additionally, an agricultural professional is considered someone who either provides agricultural advice to farmers; conducts agricultural specific farm research on agriculture; or teaches agricultural courses at university (Wheeler, 2008). In particular, Wheeler (2008) uses an ordered probit model, because the dependent variable takes more than 3 values (zero, one and two). The used dependent variable is ‘the respondents’ answers to the question ‘whether the benefits of each innovation outweighed their costs or risks for the society as a whole’ (Wheeler, 2008, p.147). Moreover, Wheeler (2008) uses two models, one fully specified and one restricted, and the regression has no issues of multi-collinearity and heteroscedasticity. Both models are significant based on their chi-squared value and R^2 (Wheeler, 2008). The Pseudo R^2 values are comparatively high (0.38 to 0.4), compared to other similar studies (Wheeler, 2008). It needs to be signified that modelling professional attitudes with the use of both survey samples (general and targeted) together in one database does not cause a problem in biasing the estimates (Wheeler, 2008). Because, it is a common method in economic adoption models to combine two samples of a farming population together (such as conventional and organic farmers) (Wheeler, 2008).

Jaeck and Lifran (2009) study how farmers behave to payments for agro-environmental services regarding enhanced ecological and policy constraints. Jaeck and Lifran (2009) divide their sample into three subsets, the one is the productivity oriented farmers, the environmentally friendly oriented farmers, the support optimizer farmers. Especially, they divide the questionnaire into 3 parts, the first part has to do with the personal details of the respondent, the second part includes the choices and the third part includes questions for the characteristics of the enterprise (Jaeck and Lifran, 2009). In addition, the researchers estimate a multinomial logit model, a sample selection model, a random parameter model and a latent class model to integrate the heterogeneity in the rice growers tastes (Jaeck and Lifran, 2009). Finally, Jaeck and Lifran (2009) use the random parameters and Latent Class Models to do better analysis by taking into consideration heterogeneity.

Equally important, Lal (2009) conducts a review for the adoption of no-till technology. By maintaining soil organic matter (SOM) above the critical level (Aune and Lal, 1997) it is important for sustaining productivity and minimizing the risks of soil and environmental degradation (Lal, 2006). Further, there are many benefits of increasing the SOM concentration and pool, because they enhance ecosystem services and improve the environment (Lal, 2009) .

Subsequently, Mazvimavi and Twomlow (2009) want to check which household and institutional factors motivate farmers to adopt conservation farming methods, as well as they study the adoption intensity. In particular, they use data from 12 districts and 232 households that practice hand hoe-based conservation farming (CF) for at least one prior season with extension and input support from non-governmental organizations (Mazvimavi and Twomlow, 2009). The conservative farming methods which had been promoted are: winter weeding, digging planting basins, crop residues, manure, basal fertilizer, application of topdressing, nitrogen fertilizer, timely weeding, crop rotation (Mazvimavi and Twomlow, 2009). Regarding the econometrics literature, three models are frequently used to analyze technology adoption: (a) linear probability models, (b) logistic function (logit), and (c) the normal density function (probit) models (Ayuk, 1997, cited in Mazvimavi and Twomlow, 2009, p. 22). In conclusion, Mazvimavi and Twomlow (2009) use a tobit model to study the adoption intensity where the dependent variable is continuous with a zero limit.

Equally important, Offermann, Nieberg and Zander (2009) examine the development of the role of government support in the financial situation of organic farms in selected Western and Eastern European countries, from the past until the present. Further, Rodriguez et al. (2009) conduct a qualitative analysis to observe the barriers for the adoption of sustainable agricultural practices with emphasis on the attitude of change agents in the US south. Additionally, Asrat et al. (2010) investigate Ethiopian farmers' crop variety preferences. Especially, they estimate the mean willingness to pay for each crop variety attribute, and identify household-specific and institutional factors that govern the preferences (Asrat et al., 2010).

Similarly, Espinosa-Goded, Barreiro-Hurlé and Ruto (2010) investigate how farmers react, when Agri-environmental schemes characteristics change. In this study a Choice Experiment is conducted to examine the farmers’ reaction to preferences for different design options in specific AES (Agri-environmental schemes) aimed at encouraging nitrogen fixing crops in marginal dry-land areas in two Spanish regions (Aragon and Andalusia) (Espinosa-Goded, Barreiro-Hurlé and Ruto, 2010). In fact, the researchers choose an error component random parameter logit model allowing for preference heterogeneity and correlation amongst the non-status quo alternatives (Espinosa-Goded, Barreiro-Hurlé and Ruto, 2010). Furthermore, Espinosa-Goded, Barreiro-Hurlé and Ruto (2010) consider as attributes flexibility for grazing, requirement for a minimum enrolled area, compulsory technical assistance and monitoring and the implementation of a fixed payment per contract.

Later, Läpple (2010) studies the factors of adoption and abandonment of organic drystock farming in Ireland. The final sample consisted of 341 organic, 41 ex-organic and 164 conventional farmers (Läpple, 2010). Moreover, duration analysis is used to study the adoption and the abandonment of organic farming (Läpple, 2010). In fact, Läpple (2010) has the hazard function and the survivor function. The author estimates two models in the case of adoption and disadoption of organic drystock farming (Läpple, 2010). Especially, Piece-wise constant exponential model (Model 1) and Weibull model (Model 2) are the duration models for the adoption of organic farming, while Piece-wise constant exponential model (Model 3) and Log-logistic model (Model 4) are the duration models for the abandonment of organic farming (Läpple, 2010).

Mayen, Balagtas and Alexander (2010) compare the productivity and the technical efficiency of organic and conventional dairy farms in the United States. The researchers use stochastic frontier analysis (SFA) framework to estimate production frontiers and measure technical efficiency (Mayen, Balagtas and Alexander, 2010). In particular, Mayen, Balagtas and Alexander (2010) use data on U.S. dairy farms from the 2005 Agricultural Resource Management Survey Dairy Costs and Returns Report.

Also, Mayen, Balagtas and Alexander (2010) estimate a probit model to obtain propensity scores: (the predicted probability of being organic), where there is a vector of farm and farmer characteristics and there is a vector of parameters to be estimated. The propensity score for each farm is the estimated probability of being organic (Mayen, Balagtas and Alexander, 2010). Moreover, Mayen, Balagtas and Alexander (2010) set the choice of organic technology as a function of farm, farmer characteristics and management practices. Farm characteristics include region, use of a milking parlor, use of automatic takeoffs on parlors, herd size, pasture usage per cow, average weight of culled cows, percentage of land rented, percentage of feed items produced in the farm, and years that the farm had operated (Mayen, Balagtas and Alexander, 2010). In addition, 'College education of the main operator', 'age', 'years that the operator had participated in the dairy industry', and 'the operator's expectation that the farm would continue to produce milk for more than 11 years' are considered as operator characteristics (Mayen, Balagtas and Alexander, 2010). Furthermore, the participation in the Dairy Herd Improvement Association (DHIA) is included in the management practices (Mayen, Balagtas and Alexander, 2010).

Then, Blazy, Carpentier and Thomas (2011) propose an ex ante evaluation of the willingness to adopt agro-ecological innovations aimed at reducing pesticide use for banana production in the French West Indies (sample of 607 banana planters, 168 from Guadeloupe and 439 from Martinique). Blazy, Carpentier and Thomas (2011) estimate a random coefficient logit model. Especially, the authors check the cross effects among respondents' statements regarding attributes to explore possible land-use conflicts or complementary effects (Blazy, Carpentier and Thomas, 2011). In detail, they create 2 questionnaires, where in the first part farmers are asked if they would adopt any of the 4 agro-ecological systems they are presented, and in the second part farmers are asked to describe their current status (Blazy, Carpentier and Thomas, 2011).

Additionally, Gomiero, Pimentel and Paoletti (2011) perform a review for the environmental influence of different agricultural methods. Organic agriculture is a part of ecological techniques, and aims at minimizing the environmental impact of the food industry, maintaining the long term sustainability of soil and reducing the use of non-renewable resources (Gomiero, Pimentel and Paoletti, 2011). Furthermore, Greiner and Gregg (2011) conduct surveys in three regions within the tropical savannas of Northern Australia. According to their research, farmers are interested in passing on the land in a good condition and they are interested in taking care of the natural environment, consequently, they want to contribute to improvements (Greiner and Gregg, 2011). Moreover, farmers want to live in a natural environment and strengthen the bond of the family by creating family properties (Greiner and Gregg, 2011). Also, farmers want to be among the best in the market (Greiner and Gregg, 2011). In addition, Greiner and Gregg (2011) emphasize policy makers should pay attention to other adoption factors related to personal and family well-being gains. Furthermore, they used the principal component analysis to obtain the factors (Greiner and Gregg, 2011).

In addition, Läpple and Van Rensburg (2011) study the adoption of organic farming or not by dividing farmers into categories: early, medium and late adopters. Also, Läpple and Van Rensburg (2011) use the multinomial logit model and data from a nationwide survey of organic and conventional farmers in Ireland conducted between July and November 2008. This study shows the different groups have different reasons for adopting organic farming due to their different structural and socio-demographic characteristics (Läpple and Van Rensburg, 2011).

García-Llorente et al. (2012) conduct research within the ecosystems framework and study the preferences of the local population for different land-use management options regarding the improvement of the current ecological and socio-economic environment and abandoning traditional agricultural methods, adaptation to new land-activities (ecotourism and wind farms) and management of water quality in a semi-arid watershed in the Mediterranean basin. Especially, two ecological (river quality and protected area), three socio-economic (traditional agriculture, ecotourism facilities and wind farms) and one monetary (tax reallocation) attributes are used (García-Llorente et al., 2012). Furthermore, García-Llorente et al. (2012) use a multinomial logit model, a multinomial logit model with interactions and a mixed logit model with interactions for their analysis.

Llewellyn, D'Emden and Kuehne (2012) examine the enabling factors for the adoption of no-tillage cropping systems, such as the demand-induced innovation by farmers and agricultural engineers, enabling agronomic technologies like herbicides and crop disease resistance, extension processes, and economic influences. In the end, Llewellyn, D'Emden and Kuehne (2012) use many types of regressions, but in the paper they present the results from a logistic regression.

Arslan et al. (2014) study the adoption of two conservation farming (CF) methods (minimum soil disturbance (MSD) and crop rotations (CR)) in Zambia. In particular, Arslan et al. (2014) use panel data methodologies to study the adoption (fixed effects probit analysis for the country and standard random effects probit model for the Eastern Province of Zambia; they also use a multivariate probit model to study the possible interdependency between the decisions to adopt these two practices). Additionally, the intensity of the adoption of CF is studied with random effects tobit model and fractional probit model (Arslan et al., 2014). Finally, it is found the reach of extension services in a village (e.g. the proportion of households that receives information on MSD or CR) affects both adoption and the intensity of adoption of both MSD and CR technologies (Arslan et al., 2014).

Also, Wollni and Andersson (2014) use original survey data to analyze the factors influencing the decision to convert to organic agriculture. Their methodology is to model the adoption decision through an expectation framework and they assume the spatial effects enter the adoption decision through some variables (Wollni and Andersson, 2014). Then, they take these variables and they try to isolate the spatial effects of other factors on these variables (Information spillovers, Perceived deviation from the social norms, and Perceived productivity spillovers on neighboring plots) and study their influence on organic farming (Wollni and Andersson, 2014). In addition, they assume that a spatially dependent process generates the decision to adopt organic agriculture, e.g. the choice observed in one location is similar to the choices made by farmers in nearby locations (LeSage and Pace, 2009, cited on Wollni and Andersson, 2014, p.122). Further, to control for such neighborhood effects potentially affecting the adoption decision, they use a Bayesian spatial autoregressive probit model: $y* = \rho Wy* + X\beta + \varepsilon, \varepsilon \sim N\left(0, \sigma^2{}_{\varepsilon} I_n\right)$. From the analysis, the spatial lag term ρ is statistically significant and this shows that spatial effects have an impact on the adoption of organic farming among the hillside farmers in Honduras (Wollni and Andersson, 2014). Furthermore, farmers, who have access to extension services, are more likely to adopt (Wollni and Andersson, 2014).

Last but not least, Paustian and Theuvsen (2017) examine which farm characteristics and farmer demographics influence farmers' choice for adoption of precision farming in German crop farming with the use of a binary logistic regression model.

1.3 Adoption Factors

Different factors determine the adoption of different agricultural technologies (Akudugu, Guo and Dadzie, 2012). Due to the multidimensionality of the human behaviour the purpose of this review is to examine adoption factors, so that the range of variables used to study the adoption of farming technologies can widen. In this section the adoption factors are presented, which are taken into consideration more often by the authors of the papers we present in the previous section.

The main factors that influence the decision to adopt a new technology are Demographic Factors and Socio-Economic Factors and include age, gender, the level of education, the size of farms, the number of the members of the family, the income of farmers, the type of the adopted technology. Further, Institutional factors such as access to credit, access to market and access to services play a significant role (Melesse, 2018).

Moreover, there are additional factors that can be statistically significant, such as: the access to irrigation system, the attitude on risk regarding agro-ecological factors, the characteristics and the results of the new farming technology (in terms of production, quality and profits), the difficulties of applying the new technology, the required time of returns of the investments on new farming technologies, the environmental impacts of the new technology, 'labor saving technologies' e.g. tractors. Also of relevance is the existence of suitable facilities for the support of the new technology, the quality of information to farmers for the new farming technology, as well the existence and creation of programmes that promote and support the new farming method (e.g. training programmes for new farming techniques) (Keba, 2019). In addition, interaction with other farmers can promote the use of new agricultural technologies (Conley and Udry, 2010; Keba, 2019). Farmers may hesitate to adopt a new technology in the absence of compensation policy in the case the new technology does not provide satisfying yields (Chi and Yamada, 2002). Especially, Lips and Gazzarin (2008) conduct a Choice Experiment and confirm the case of dairy farmers that there are no nonprecuniary incentives, and a policy programme that encourages farmers to stop their milk production would fail to achieve that purpose. Because of the high annual amount of money required by farmers in order to stop their milk production (Lips and Gazzarin, 2008).

Moreover, according to Sparks, Conroy and Sandilands (2008), more than 50% of the farmers, who participate in their survey, mention the main factor to adopt organic methods is commercial. Also, farmers state bureaucracy is a problem for their businesses (Sparks, Conroy and Sandilands, 2008) . More specifically, 40% of poultry keepers consider the ecological/organic rules both not clear and complex at the same time (Sparks, Conroy and Sandilands, 2008). According to Häring et al. (2001) ecological farming, and more specifically organic farming, fulfils some goals of the Common Agricultural Policy of the European Union, which can support the promotion of ecological farming. The outputs from organic farming are much healthier for consumers and on many occasions the average profits of ecological farming are at least equal to the profits of conventional farming. Moreover, 'indirect effects' like the increase of the employment rate in the areas because of the healthier environment can boost the economic growth in rural areas. According to Offermann, Nieberg and Zander

(2009) , direct financial support from governments is important for the sustainability of organic farming in countries of Western and Eastern Europe. Lee (2005) focuses on the key factors for the adoption of sustainable agricultural methods in developing countries and states the economic incentives such as the decrease of the transaction costs, can boost the adoption of sustainable agricultural methods. Moreover, institutions and networks have a huge impact on the adoption of sustainable agricultural methods, such as the collaboration with research networks (Lee, 2005). Furthermore, Stuart, Schewe and McDermott (2014) state the barriers for reducing nitrogen fertilizer are the yields and also the contracts with dominant firms in the commodity market.

Another significant factor is welfare. Sparks, Conroy and Sandilands (2008) additionally find the second most significant factor is the welfare. Also, Greiner and Gregg (2011) claim the main incentives for the adoption of a new farming technology are not only money-related. Especially, Greiner and Gregg (2011) claim money conditions, such as the minimization of the tax rate, the maximization of their profitability, and the high incomes are among the last incentives.

Summing up, according to Knowler and Bradshaw (2007) no adoption factor has a universal application and for this reason regional studies for the adoption of farming technologies are important. The commonly used adoption factors as seen in the most cited papers are presented below. The adoption factors are discussed according to their importance, which is derived by the frequency used within the existing literature. We start with most cited adoption factors and we conclude with the least cited.

Economic Factors

An adoption factor taken into account by researchers very seriously are the economic ones. Gomiero, Pimentel and Paoletti (2011) mention the economic results of organic farming are important for its adoption. Moreover, Gomiero, Pimentel and Paoletti (2011) mention the economic gains from agricultural management should be extended to other fields for the calculation of the farming cost-benefit analyses (e.g. landscape preservation, energy efficiency). More specifically, solvency is statistically significant and has a negative influence on the adoption of innovative farming techniques in the study of Diederen, van Meijl and Wolters (2003). In addition, Pimentel et al. (2005) provide previous studies and descriptive statistics to illustrate the differences and the similarities of the organic and conventional farming methods. According to their study, organic foods are more expensive, and the net economic return per ha is often equal or higher than conventionally products (Pimentel et al., 2005).

Moreover, the results of McBride and Greene (2007) state there may be economic incentives for small existing dairies that have already committed much of the fixed investment in milk production to consider transitioning to the organic technique. Also, Wheeler (2008) finds the belief in the financial profitability of organic farming is statistically significant. In addition, yield is statistically significant in all the models of Jaeck and Lifran (2009).

Lal (2009) reviews the economic factors for the adoption of no-till technology in developing countries. The decrease in yield, the price control, the lack of credit and the alternative uses of crop residues are statistically significant for the adoption of no-till technology in developing countries (Lal, 2009). Also, in the analysis of Rodriguez et al. (2009) one of the barriers for the adoption of sustainable agricultural practices is the economic factor, which includes cost, financial concerns, uncertainty, inadequate programmes for the provision of incentives, profitability, equipment change, risk, low commodity prices, economic conditions. More specifically, in the table with the responses to the question, “What were the major obstacles or barriers that producers must overcome to adopt sustainable agricultural practices?” the first obstacle is the economic factor according to the 56% of the responses (Rodriguez et al., 2009).

Moreover, Espinosa-Goded, Barreiro-Hurlé and Ruto (2010) include fixed premium and the interaction effect of fixed premium and participation in the Agri-environmental Design Schemes and both terms are statistically significant. Additionally, Blazy, Carpentier and Thomas (2011) incorporate economic factors and they find the price and subsidies are statistically significant with a positive impact for both the full sample and for the Guadeloupe sample and the Martinique one separately. From their analysis the interaction effects ‘Ecotourism* Protected Areas imposes an economic limitation’ and ‘River Quality * Protected Areas imposes an economic limitation’ are statistically significant with a negative impact on the adoption of more ecological land-use management methods (Blazy, Carpentier and Thomas, 2011).

Next, Arslan et al. (2014) observe the wealth and market access have a greater impact on the adoption of crop rotation technologies than minimum soil disturbance. More specifically the wealth index is not statistical significant in the whole sample in neither the random effects tobit models, nor their pooled fractional probit models (Arslan et al., 2014). However, the agricultural wealth index is statistically significant in the crop rotation technology in both pooled fractional probit and random effects tobit models (Arslan et al., 2014).

Profitability

Another adoption economic factor is profitability. From the study of Läpple (2010) it can be noted that increasing profitability of conventional farming slows the adoption of organic farming. Moreover, according to Läpple and Van Rensburg (2011) profits are statistically significant for early and medium adopters.

Cost

Cost is also a significant adoption economic factor. Agricultural innovations are not adopted due to their high costs (Fujisaka, 1994). Shi and Gill (2005) show through their simulations high transaction costs can be serious obstacles for the adoption of farming methods. Another cost, which is taken into consideration by Birol, Smale and Gyovai (2006) for the valuation of agrobiodiversity and is statistically significant, is the food expenditure.

Moreover, McBride and Greene (2007) study the influence of choosing organic method on different levels of milk production costs. Due to the little information about the relative costs and returns of organic and conventional milk production, McBride and Greene (2007) study the cost, too. According to McBride and Greene (2007) organic dairies have production costs about $5 to $7 per cwt higher than conventional dairies and receive an average milk price premium of $6.69 per cwt. Furthermore, the actual costs and returns during the transition period to organic methods may be changing as organic milk processors offer additional incentives for producers to switch to the organic technology (McBride and Greene, 2007).

Also, Espinosa-Goded, Barreiro-Hurlé and Ruto (2010) conclude farmers show a strong preference for maintaining their current management strategies; however, significant savings in cost or increased participation could be obtained by modifying some Agri-environmental Schemes attributes. In addition, García-Llorente et al. (2012) include in their analysis the cost, defined as tax reallocation from the monetary investment of the European Social Fund Operational programme for Andalusia. The attribute cost is statistical significant in all their models (García-Llorente et al., 2012). Nevertheless, Knowler and Bradshaw (2007) note the impact of production costs on Conservation Agriculture is always insignificant in the projects they study.

Income

Income is one of the most common variables policy makers and adopters take into consideration for the adoption of a new farming method. Ajayi et al. (2003) take into account income in their study and they set it at the factors that affect the decision process of farmers in a positive way.

Moreover, Ayers and Walters (1991, cited on Khanna and Zilberman, 1997, p.35) show the implicit rates of discount that producers and consumers use, are typically much higher than real rates of interest and have different values depending on the income and age of consumers and the financial and credit situation of producers.

Also, in the paper of Jacobson et al. (2003) the percent income from farm (income (%)) is connected with two statistical significant relationships, the one is income (%) - Spend considerable money on pest management and the other one is income (%) - Leaf-eating insects a serious problem. Additionally, the relationships of income - Insect pests cause damage and income - Spend considerable money on pest management are statistically significant. Furthermore, these relationships are statistically significant for the adoption of bird-friendly farming practices of northern Florida’s conventional and organic farms (Jacobson et al., 2003).

Later, Birol, Smale and Gyovai (2006) discover income is statistically significant in terms of differences for the adoption of home garden. Furthermore, according to Asrat et al. (2010) yield stability is statistically significant for the choice of crop varieties. Especially, Asrat et al. (2010) concludes farmers are willing to forego some extra income or yield to obtain a more stable crop type. Also, the frequent limitation of cash-flows is found statistically significant in the paper of Blazy, Carpentier and Thomas (2011).

Off-farm Income

Another adoption economic factor taken into consideration quire often is the off-farm income. Daberkow and McBride (2003) also note the occupation of the farmer (defined as retired or if he has job out of the farming sector or full-time) is statistically significant. In addition, Knowler and Bradshaw (2007) present off-farm income as one of the main variables for the adoption of conservation agriculture. Later, Jaeck and Lifran (2009) detect the compensatory payment, defined as an extra income offered either by the market or by the Common Agricultural Policy, is statistically significant in all their models. Furthermore, in the analysis of García-Llorente et al. (2012) the attribute Ecotourism, which includes off-farm activities, is statistically significant in all their models.

However, Ajayi et al. (2003) take into account the off-farm income of farmers in their review and it has no direct impact on the decision process of farmers for the adoption of improved fallows. Finally, Läpple (2010) discovers the off-farm job is not statistically significant for the adoption of this technology.

Extensions Services

Extension services is also another factor that needs to be taken into account. Fujisaka (1994) visits the field in 5 cases and discusses with the adopters and non-adopters and she studies some project documents regarding the adoption of innovative methods for the sustainability of upland agriculture. According to Fujisaka (1994) one of the reasons of not adopting innovative agricultural methods is that extension services fail. Additionally, according to Kalaitzandonakes and Kalaitzandonakes and Dunn (1995, cited on Khanna and Zilberman, 1997, p.34) extension services can affect the heterogeneity among farmers.

Also, Adesina et al. (2000) mention the contact with extension services is statistically significant for the adoption of alley farming variants. From the econometric analysis of Adesina et al. (2000) farmers, who have contracts with extension agencies, are more willing to adopt. In addition, Adesina and Chianu (2002) mention the statistically significance of the contact with extension services for the adoption of alley farming in Nigeria.

Moreover, limited access to information is a significant barrier to the use of alternative farming methods in Jinshan County in China (Shi and Gill, 2005). In the analysis of Genius, Pantzios and Tzouvelekas (2006) for organic farming conversion, the number of extension outlets is statistically significant. In addition, Knowler and Bradshaw (2007) mention the extension assistance and its importance is found in nine studies out of the thirty-one they examine. Also, the existence of extension services and non-government organization are statistically significant for both the adoption intensity of conservation farming and conservation farming methods in Zimbabwe (Mazvimavi and Twomlow, 2009).

Technical advisory service is also statistically significant for the investigation of Agri-environmental schemes design (Espinosa-Goded, Barreiro-Hurlé and Ruto, 2010). Later, in the study of Läpple and Van Rensburg (2011) the factor information (from extension services) is statistically significant for the late adopters and the information (from media) is also statistically significant in the same research project. Furthermore, Llewellyn, D'Emden and Kuehne (2012) find the adoption of no-tillage is correlated with the use of extension agent. Extension services are also statistically significant for the adoption of conservation farming and minimum soil disturbance methods in Zambia (Arslan et al., 2014).

Additionally, Wollni and Andersson (2014) notice that farmers, who have access to extension services and farmers, who have access to a neighborhood network that receives extension on more topics, have a higher probability to adopt organic agriculture, since both variables are statistically significant. However, Llewellyn, D'Emden and Kuehne (2012) take into account the extension procedures, but they are not statistically significant.

Area

Another factor that is significant for the adoption of a farming technology is the area and its characteristics. Fujisaka (1994) mentions the social conditions in the area has an impact on farmers to adopt sustainable agricultural methods, because in the examined area the probability of war is high. From the econometric analysis of Adesina et al. (2000) farmers, who live in areas with very high population pressure because of food crops expansion, are less willing to adopt alley cropping technology. And farmers, who live in areas with fuel wood scarcity, are more willing to adopt (Adesina et al., 2000). Also, Daberkow and McBride (2003) mention the location of the farm is statistically significant.

Birol, Smale and Gyovai (2006) also find home garden area is statistically significant in terms of differences of at least one pair of the examined areas for the adoption of home garden. In addition, Birol, Smale and Gyovai (2006) detect the field land, which is cultivated, is statistically significant for the farmers' valuation of agrobiodiversity on Hungarian small farms.

Further, McBride and Greene (2007) find the location of the dairy operation is statistically significant. Wheeler (2008) also notices that working in a natural resource management area is statistically significant with a positive impact on the adoption of organic farming. In the study of Mayen, Balagtas and Alexander (2010) the location of the farms is statistically significant. In addition, the part of land, which is used for the cultivation of banana, is statistically significant in the paper of Blazy, Carpentier and Thomas (2011). Also, Läpple and Van Rensburg (2011) confirm the utilizable farming area is statistically significant.

García-Llorente et al. (2012) spot the attributes protected areas and traditional agriculture (defined as traditional crops surface area) are statistically significant. Additionally, Llewellyn, D'Emden and Kuehne (2012) detect the location is statistically significant with the earlier no-tillage adoption. Further, Wollni and Andersson (2014) show the adoption of organic farming depends on the location. The spatial lag term ρ is positive and statistically significant and depicts the neighborhood effects and farmers are more likely to adopt if their neighbors already use organic farming (Wollni and Andersson, 2014). The distance of the farm from the main market has a negative effect and is statistically significant for the conversion into organic farming (Wollni and Andersson, 2014).

Education of farmers

Education is another adoption factor researchers study for the adoption of new ecological farming methods. D'souza, Cyphers and Phipps (1993) mention the statistically significance of education for the adoption of Sustainable Agricultural Practices. According to Dinar and Yaron (1990, cited on Khanna and Zilberman, 1997, p.34) higher levels of education (and younger ages of farmers) are statistically significant in adopting computer technologies for farm management and irrigation. Moreover, Adesina and Chianu (2002) note education is statistically significant for the modification of the alley technology. Later, Jacobson et al. (2003) detect the relationships education-pest control, education-insect pests cause damage, education-spend considerable money on pest management are statistically significant in their project.

Additionally, Birol, Smale and Gyovai (2006) notice education is statistically significant in terms of differences of at least one pair of the examined areas for the adoption of home garden on regional level. Also, Genius, Pantzios and Tzouvelekas (2006) find education is statistically significant for the adoption of organic farming practices. Moreover, Wheeler (2008) conduct a survey to check how increased knowledge and experience have an impact on attitudes towards organic agriculture and he finds education is also one of the variables with the greatest influence on organic agriculture. However, education is mentioned as barrier for the adoption of sustainable agricultural practices in the study of Rodriguez et al. (2009).

Furthermore, while Llewellyn, D'Emden and Kuehne (2012) examine the enabling factors for the adoption of no-tillage cropping systems, they find higher education is significantly associated with a greater rate of adoption. According to Arslan et al. (2014) education has a greater impact on the adoption of crop rotation than that of MSD for the adoption of conservation farming methods in Zambia.

Nonetheless, Ajayi et al. (2003) observe education has no effect on farmers' decision to adopt improved fallows. This comes in accordance with Diederen, van Meijl and Wolters (2003), who also find education does not affect the adoption of an agricultural innovation in the Netherlands.

Age of farmers

Researchers consider age of farmers as a key element for the adoption of a new ecological farming technology. Age is statistically significant and affects the adoption of sustainable agricultural practices in Western Virginia (D'souza, Cyphers and Phipps, 1993). Moreover, according to Dinar and Yaron (1990, cited on Khanna and Zilberman, 1997, p.34) higher levels of younger ages of farmers are statistically significant in adopting computer technologies for farm management and irrigation. Also, Jacobson et al. (2003) find the relationship age-(My farm provides good habitat for birds) is statistically significant for the adoption of bird-friendly farming practices of northern Florida's conventional and organic farmers.

In addition, from the analysis of Genius, Pantzios and Tzouvelekas (2006) for organic farming conversion, one of the statistically significant variables is the age of farmers. Furthermore, another statistically significant variable for the marginal effects of the probability of farmers adopting partial or full organic farming is the age of farmer. Also, according to Wheeler (2008) age and working age have a negative impact on the shape of overall organic mentality. Some respondents claim in the qualitative research of Rodriguez et al. (2009) that age is an obstacle for the adoption of sustainable agricultural practices in the US South. Also, from the estimates of Mayen, Balagtas and Alexander (2010), age is statistically significant for the comparison of the productivity and the technical efficiency of organic and conventional dairy farms in the United States. Although, age is statistically significant in regional level –in Guadeloupe- it is not in the full sample for the adoption of agro-ecological innovations in the French West Indies (Blazy, Carpentier and Thomas, 2011). Further, from the multinomial logit regression analysis of Läpple and Van Rensburg (2011) the age is noticed statistically significant. Also, the age of the household head is statistically significant for the decision of farmers to convert to organic agriculture (Wollni and Andersson, 2014).

However, Ajayi et al. (2003) observe age has no impact on the decision of farmers to adopt improved fallows. In addition, in the study of Birol, Smale and Gyovai (2006) age is not statistically significant.

Experience

Another factor taken into account by researchers and policy makers for the adoption of farming techniques is the experience of farmers in different fields. Kebede, Gunjal and Coffin (1990) observe farming experience in single-ox and pesticides technologies are statistically significant. According to Kalaitzandonakes and Dunn (1995, cited on Khanna and Zilberman, 1997, p.35) experience is a factor that affects heterogeneity among farms and the learning and transition costs of adoption of precision technology. Adesina and Chianu (2002) also note the number of years of experience in alley farming is statistically significant. More specifically, Daberkow and McBride (2003) find the computer literacy is statistically significant for the adoption of Precision Agricultural Methods. Moreover, Wheeler (2008) finds the knowledge for organic methods is statistically significant and it has a positive impact.

Later, Mazvimavi and Twomlow (2009) find that experience with conservation farming technology has a positive coefficient and is statistically significant. It can be deducted from their analysis the longer a household practices conservation farming, the more likely it is to take up all eight components of the CF package (Mazvimavi and Twomlow, 2009). Also, Paustian and Theuvsen (2017) define the experience in five time horizons, of which two levels are statistically significant- experience crop farming (<5 years) and (16-20 years).

In conclusion, Daberkow and McBride (2003) define awareness and adoption connected with the profits under the assumption of full information. However, after the logit regression the researchers find awareness [1] did not affect the adoption of precision agriculture methods in a statistically significant way (Daberkow and McBride, 2003).

Environmental Attitude

Environmental attitude needs to be considered regarding the adoption of a new farming technology. Burton, Rigby and Young (2003) notice the variables regarding if the farmer is concerned about local, national or global environmental issues and the factor 'farmers' belief that organic agriculture is better for the environment' are statistically significant and have a positive impact on the adoption of organic horticultural technology in the UK.

Similarly, Genius, Pantzios and Tzouvelekas (2006) also spot the awareness of farmers for environmental issues is statistically significant. Moreover, Knowler and Bradshaw (2007) mention the factor Awareness of environmental threats demonstrates behavioural consistency, where it is statistically significant with a positive influence on the adoption of conservation agriculture.

In addition, Wheeler (2008) discovers the belief of the environmental superiority of organic farming is statistically significant and has a positive impact on the benefits of each innovation outweighed their costs or risks for society as a whole. Wheeler (2008) also finds the belief in the improved characteristics of organic food is statistically significant and has a positive influence. Moreover, according to Wheeler (2008) the factor opinions regarding the environmental benefits of organic methods is the variable with a great influence on the adoption of organic farming. Later, Läpple (2010) mentions the attitudes of farmers are statistically significant, and farmers who care more about the environment are more likely to adopt organic methods. Furthermore, in the

[1] Awareness = farm operators know about precision agricultural technologies

study of Läpple and Van Rensburg (2011) environmental attitude is statistically significant.

Environmental Conditions

Environmental conditions have one of the most crucial roles at the decision process of farmers. D'souza, Cyphers and Phipps (1993) take into account the environmental factors, in their case the ground-water, which is showed to be statistically significant in the adoption of sustainable agricultural techniques. In addition, Mazvimavi and Twomlow (2009) detect rainfall is statistically significant in their tobit model and show farmers in high rainfall areas practice more Conservation Farming methods. Moreover, in the study of Asrat et al. (2010) for both teff and sorghum varieties, the independent variable environmental adaptability is statistically significant. In this study, the environmental adaptability is defined as whether the variety is resistant or tolerant to environmental stress factors such as poor soil, poor rainfall, and frost (Asrat et al., 2010).

Afterward, in the study surface of Espinosa-Goded, Barreiro-Hurlé and Ruto (2010), grazing (in enrolled surface) and the interaction term grazing * participation is statistically significant. Also, Mayen, Balagtas and Alexander (2010) note the seasonal dry-off is statistically significant for the adoption of farming technology in the US dairy farms. Moreover, the quality of the river is statistically significant in the paper of García-Llorente et al. (2012). Furthermore, Arslan et al. (2014) found farmers use MSD as a tool to a strategy to mitigate the risk of rainfall variability.

Hired Labour

Labour productivity is one of the key factors for the adoption of organic farming methods (Gomiero, Pimentel and Paoletti, 2011). In addition, organic farming technologies are more labour intensive than conventional ones (Gomiero, Pimentel and Paoletti, 2011).

D'souza, Cyphers and Phipps (1993) spot employment is statistically significant for the adoption of sustainable agricultural practices. According to Pimentel et al. (2005) labor inputs are on average 15% higher in organic farming systems , but they are more evenly distributed over the year in organic farming systems than in conventional ones. Ajayi et al. (2003) find in their review that labour constraints have a negative impact on the decision process of farmers to adopt improved fallows. However, Diederen, van Meijl and Wolters (2003) note labour resources are statistically significant with a positive impact for the adoption of an innovation-farming method in Netherlands.

Nonetheless, Knowler and Bradshaw (2007) point out in their review that hired labour is one of the seven universal variables with a consistent behaviour and is statistically insignificant in the studies they examined.

Farm size

Another common factor researchers take into account is the farm size. Kebede, Gunjal and Coffin (1990) note farm size is statistically significant in all farming technologies they study. In addition, Ajayi et al. (2003) notice in their review the farm size is connected with the adoption of improved fallows in a positive way. Moreover, Burton, Rigby and Young (2003) observe the variable farmers' belief that larger farms cause damage to the environment and it is statistically significant, but it has a positive impact on the adoption of organic horticultural technology in the UK. Daberkow and McBride (2003) also detect farm size is one of the statistically significant variables in their analysis.

Jacobson et al. (2003) discover the relationships farm size - insect pests cause damage, farm size - spend considerable money on pest management, farm size - leaf-eating insects a serious problem, would like to attract birds to farm if it would lower- farm size are also statistically significant. In accordance to this, McBride and Greene (2007) also find the size of the dairy operation is statistically significant, as well as Lal (2009) mentions the small size farm is important for the adoption of no-till technology in developing countries. Finally, Paustian and Theuvsen (2017) also find farm size is statistically significant in their analysis.

Social Norms

Researchers often examine social norms with regard to the adoption of a new farming technology. Burton, Rigby and Young (2003) examine if the main information source is another farmers and this factor is statistically significant in their study. Additionally, Diederen, van Meijl and Wolters (2003) take into account the cooperation, which is statistically significant and has a positive impact. Moreover, in the analysis of Läpple (2010) social interaction is statistically significant. Later, Läpple and Van Rensburg (2011) note the factor if the farmer knows other organic farmers is statistically significant.

Furthermore, according to Wollni and Andersson (2014) social conformity is statistically significant and it affects the adoption decision of farmers, showing farmers are significantly more likely to adopt organic agriculture, if they believe their neighbors would be approving of their decision. Also, Wollni and Andersson (2014) note positive productivity effects on neighbor's plot is statistically significant for the decision process of farmers to convert to organic agriculture.

Household size

The size of households is also considered by researchers. Ecological farming technology is more labour intensive than the conventional one (Gomiero, Pimentel and Paoletti, 2011). May farmers use the members of their families in their agricultural activities, so the family size matters for the adoption of farming methods. Adesina and Chianu (2002) find the family size is statistically significant for the modification of the alley technology. While, family size is statistically significant, as well as in the study of Birol, Smale and Gyovai (2006) for home gardens in Hungary.

Läpple and Van Rensburg (2011) also find the number of the members of the household is statistically significant only for the early adopters. Additionally, Wollni and Andersson (2014) find the number of the household members is statistically significant and has a positive impact. Despite these studies, Ajayi et al. (2003) present in their review the size of household has either ambiguous or no effect at the adoption of improved fallows.

Gender

Gender also has a huge impact with regard to adopting a new farming technique. From the analysis of Adesina et al. (2000) it is found the gender of the farmer is statistically significant to adopt and use of alley farming variants. Moreover, one of the statistically significant factors for the adoption of alley farming in Nigeria is gender (Adesina and Chianu, 2002). Additionally, one of the statistically significant factors for the adoption intensity of conservation farming is gender (Mazvimavi and Twomlow, 2009). Gender is also statistically significant for the adoption of organic horticultural technology in the UK (Burton, Rigby and Young, 2003). Last but not least, in the review of Lal (2009) gender is among the important factors for the adoption of no-till farming technology in developing countries. However, according to the review of Ajayi et al. (2003) gender has no impact regarding farmers' decision to establish improved fallows.

Tenure

Fujisaka (1994) detects insecure land tenure (because of the fear that the owners could take the land and take advantage of the investment or they may not be able to till the land until the land pays the returns) is a major obstacle for not adopting sustainable agricultural methods. Also, Jacobson et al. (2003) find the relationships tenure - (Would use pesticide alternatives) and tenure – (My farm provides good habitat for birds) are statistically significant. Furthermore, Birol, Smale and Gyovai (2006) find the field land, which is owned by farmers, is statistically significant in their study.

Social Factors

Social factors are among the most frequent factors of adopting a new agricultural technology. Rodriguez et al. (2009) take into account some social factors (change in beliefs, perceptions of inefficacy of some sustainable agricultural methods, peer pressure to avoid sustainable agricultural methods, lack of examples for other farmers, misleading attitude, conventional/sustainable opposite method.) as obstacles for the adoption of sustainable agriculture practices.

Risk

Shi and Gill (2005) demonstrate risk aversion could be a significant obstacle for the adoption of alternative agricultural methods. Moreover, Jaeck and Lifran (2009) find risk to be a statistical significant factor in all their estimated models. While, Läpple and Van Rensburg (2011) find the attitude about risk (more risk averse) is statistically significant for medium and later adopters.

Expertise of the Farm

Daberkow and McBride (2003) take into account the expertise of the farm and they find it is statistically significant in both stages of the logit regression for the adoption of Precision Agricultural Methods. In addition, Genius, Pantzios and Tzouvelekas (2006) find the expertise of the farm is statistically significant for the conversion of farm into organic.

1.4 Conclusion

The purpose of this chapter is to inform readers about the factors for the adoption of new farming technologies. Vast literatures exist on factors that determine agricultural technology adoption (Mwangi and Kariuki, 2015). The purpose of the analysis of technology adoption from the economic perspective is to explain adoption behavior in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Feder, Just and Zilberman, 1985). These factors are generally divided into categories for the convenience of researchers and policy makers. The most usual categorization is economic, social and institutional factors (Akudugu, Guo and Dadzie, 2012; Melesse, 2018). Each factor can affect the adoption of a new farming technology either in a positive or a negative way. The adoption factors of a farming technology does not always have the same effect on adoption, rather the impact depends on the type of technology being introduced (Mwangi and Kariuki, 2015).

The decisions of farmers about whether and how to adopt new technology are affected by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances (Loevinsohn et al., 2013). By understanding the adoption factors of a farming technology, policy makers can plan and implement technology related programmes for dealing with the challenges of food production especially in the developing countries (Mwangi and Kariuki, 2015). The success of these programmes is for adopters to increase their productions and leading to constant socio-economic development (Mwangi and Kariuki, 2015). Moreover, the information about the adoption factors can promote more a new farming technology that enhances sustainable production of food and fiber (Mwangi and Kariuki, 2015). This promotion is therefore significant for sustainable food security and economic development (Mwangi and Kariuki, 2015).

According to Akudugu, Guo and Dadzie (2012) policy makers should plan and implement policies that take advantage of the factors that positively influence farmers' adoption of new farming technologies and to mitigate the negative ones. These policies can be planned and implemented more efficiently if policy makers know which factors to take into account. Since, there is no adoption factor that has a universal behaviour (Knowler and Bradshaw, 2007), the information regarding adoption factors can provide and promote ecological farming methods more effectively.

Analyzing consumer preferences and willingness-to-pay (WTP) for sustainable foods produced using new farming technologies is important, so as to enhance the uptake of innovations that accelerate the transition towards sustainable food systems (Ali, Ang and van der Fels-Klerx, 2021).

In this chapter we present studies that include observable and unobservable adoption factors. There are studies in the literature which take into account these unobservable factors (e.g. attitude, social norms). It is an undeniable fact the decision process of economic agents depends on unobservable factors, as well. These factors need to be taken into account when it comes to the adoption of a new farming technology. In the next chapter we present the theoretical models of adopting a new technology, which quantify the decision process for the adoption of a new technology and include these unobservable adoption factors.

2. Methodological frameworks for the adoption of farming technologies

2.1. Introduction

We study the methodological frameworks that have been used for the adoption of new technologies and they are most commonly found in the literature. These methodologies come from the field of Psychology and Economics. In the beginning of the chapter we present the psychological theories and their variables and then we proceed with the framework of Expected Utility Theory (EUT). The goal of this chapter is to exhibit the advantages and disadvantages of the presented methodologies.

Many research theories have been developed to analyse the reasons for the adoption of new technologies both information system technologies and farming technologies. It is important to predict human behaviour regarding the usage of new technologies, because policy makers can plan and implement suitable policies according to the needs of people and so that social welfare can be increased.

In respect of farming it is important to understand farmers' attitude towards ecological methods and technologies of farming, the impact of such methods and technologies of adoption of these techniques and their rate of adoption. To investigate different theories and factors and check farmers' attitude, we combine the elements of the Theory of Planned Behaviour (TPB), the Theory Acceptance Model (TAM), the Theory of Reasoned Action (TRA) and the Theory of Diffusion of Innovations (DIT) and to study them in order to answer our *research question*, which is: *How can the adoption of ecological agricultural technologies be studied?*

2.2 The theories

Here we will examine psychological theories on adoption of a new technology, which are The Theory of Reasoned Action (TRA) (Ajzen, 1985), the Theory Acceptance Model (TAM) (Davis, 1985), the Theory of Planned Behaviour (TPB) (Ajzen, 1991) and the Theory of Diffusion of Innovations Theory (DIT) (Rogers, 2010). In addition, we present Expected Utility Theory (EUT) (Daniel Bernouli, 1738 cited in Eatwell, Milgate and Newman, 1990, p.70) which is used extensively in the field of Agricultural Economics.

2.2.1 TRA

According to Ajzen (1985) the purpose of the TRA is to predict voluntary behaviours (e.g. prayer) and help researchers to find the psychological factors behind these behaviours. TRA consists of attitude and subjective norms (Ajzen, 1985). However, there are cases where behaviours are not voluntary (e.g. people who cannot stop smoking) because they are influenced by internal or external factors, so people do not have control over their behaviour (Ajzen, 1985). Regarding the adoption of ecological methods of farming, researchers can seek for both intrinsic (e.g. personal preference) and extrinsic motivations (e.g. practicality) (Ajzen, 1985). Intrinsic factors are the ones that satisfy personal preferences, while extrinsic factors have to do with practical conditions such as incentives (Ajzen, 1985).

2.2.2 TPB

The TPB model is an extension of the TRA methodology (Ajzen, 1985). The TPB addresses attitude, subjective norms and perceived behavioural control (control upon the factors that affect behaviour) (Ajzen, 1991). Ajzen (1991) claims that behaviour is a joint function of purposes and perceived behavioural control. By looking at intentions and perceptions of behavioural control, the behaviour of the economic agents can be predicted. Moreover, the TPB assumes behaviour is a function of salient information and beliefs in coordination with the behavior (Ajzen, 1991). It is important to mention the three types of beliefs referred to in the TPB namely behavioural beliefs, normative beliefs and control beliefs(Ajzen, 1991).

Another important aspect of the TPB is the relationship between the three types of beliefs: behavioural, normative, and control, and between the related constructs of attitude, subjective norms, and perceived behavioural control (Ajzen, 1991). Another significant attribute of the TPB is past behaviour, which should be considered as a reflection of all components which shapes the behaviour we study (Ajzen, 1991).

2.2.3 TAM

TAM is also used widely for studying adoptions of new technologies. Fishbein (1967, cited in Davis, 1985, p.15) developed his own theoretical model for behaviours on which the TAM was based. In Fishbein's model the independent variable is behaviour, which equals the behavioural intention, which Fishbein claims, is the independent variable (Davis, 1985). The dependent variables of the model are the attitude, motivating behaviour and the social influence the agent receives from other people (Davis, 1985). According to the TAM, the variables that affect the attitude for adopting a new technology are perceived ease of use and perceived usefulness, and this attitude will determine the adoption of the new technology (Davis, 1989). TAM does not include the social norms, because respondents will not have information to express their expectations for the new technology (Davis, 1985).

2.2.4 DIT

Other attributes for the adoption of ecological techniques of farming can be found in the DIT. According to Rogers (2010) diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system.

The 5 characteristics of the DIT (Rogers, 2010, p.15):

1. Relative advantage: the characteristic where an innovation is considered to be better than the older technology.
2. Compatibility: an innovation is considered to be constant with the principles, past behaviours and needs of farmers.
3. Complexity: how difficult is to adopt a new innovation
4. Trialability: the testing of the innovation
5. Observability: other people can see the results of the innovation.

In addition, the beliefs of the potential user regarding the characteristics of an innovation influence the adoption of the innovation (Rogers, 2010).

According to the following theories we presented (TPB, TRA, TAM and the DIT), intentions and perceptions are all important variables for the prediction of human behaviour, in this case, the adoption of agro-ecological methods of farming.

2.3. Variables

2.3.1 Attitude

The first variable we will examine is the attitude towards the behaviour and the degree to which a person has a positive or negative opinion about a behaviour. Attitude is found in most theories (e.g. TPB, TRA, TAM) we study. A positive attitude towards a technology is significant in its adoption, and the attitude of farmers can be shaped by training programmes (Dwivedi et al., 2019). Moreover, farmers' attitude can be influenced by other farmers or people, by the facilitating conditions and by social factors (e.g. demand for healthier vegetables). The researchers add user attitude as a mediating construct (Dwivedi et al., 2019). According to Dwivedi et al. (2019, p.723) attitude has an impact from perceived usefulness and perceived ease of use as the TAM claims. Dwivedi et al. (2019) indicate facilitating conditions and social influence can shape attitude and behavioural intention directly.

Expectancy theory, self-efficacy theory, behavioural decision theory, diffusion of innovations and marketing theory were used to point out the usefulness and ease of use as factors considered to have a huge impact on attitude and, as a result of this, they have an impact on adoption of a new technology (Davis, 1989). Given that ecological farming is more labour intensive, this can stand as an obstacle or an opportunity for farmers' attitude towards adopting ecological techniques (Offermann and Nieberg, 2002). Therefore, it is important to determine the attitude of farmers (Dwivedi et al., 2019).

In addition, attitude can affect performance expectancy and effort expectancy (Dwivedi et al., 2019, p.723). It is important for a technology to be considered useful, otherwise it will not be used (Davis, 1989). Perceived usefulness and perceived ease of use have an impact on attitude in TAM (Davis, 1985). Hsu and Chiu (2004) separated the attitude towards e-services into perceived usefulness, perceived risk and perceived playfulness. By e-services Hsu and Chiu (2004) mean support services such as consulting, outsourcing, website design, electronic data interchange, payment transfer, and data storage backups. According to Hsu and Chiu (2004) the satisfaction for new technology has the highest estimated coefficient and it has the largest impact on the attitude for the continuance of usage of the e-service technologies. It should be noted that differences have been noticed between the observed and actual performance of some technologies in some Minimum Income Standard studies (Davis, 1989, p.319). However, the perceived controllability is statistically significant and it has an impact directly on the continuance of usage of the e-service technology (Hsu and Chiu, 2004).

2.3.2 Subjective norms

The second variable of importance is subjective norms, which refers to the perceived social pressure to behave or not like the rest social group. According to Dwivedi et al. (2019) facilitating conditions and social influence can shape attitude and behavioural intention directly and, as a result, it affects the adoption of a new technology. Subjective norms are included in TPB and TRA models (Ajzen 1985;1991).

2.3.3 Perceived Behavioural Control

The third variable is the degree of perceived behavioural control, which applies to the perceived ease or difficulty to adopt the behaviour. According to the findings of a number of studies (Ajzen, 1991, p.189), a person's own personal opinion on how easy or difficult the new behavior has more influence than perceived social pressure on the adoption of a behaviour. Perceived behavioural control is included in TPB model (Ajzen, 1991) and in the variable Compatibility in the DIT (Rogers, 2010).

2.4 EUT

The purpose of Psychology is to interpret and explain the emotional and cognitive mechanisms of human behavior, while Economics study decision outcomes (Fréchette and Schotter, 2015). According to Economics every agent has stable and coherent preferences, and she rationally tries to maximize them (Rabin, 1998). On the other hand, Psychology recommends various changes to the concept of human rational choice (Rabin, 1998).

Uncertainty exists in every economic activity (Gilboa and Marinacci, 2016). The decisions of farmers are affected by risk, and EUT is a tool to study this (Bocquého, Jacquet and Reynaud, 2014). EUT is used for the adoption of farming technologies (Buschena, 2003).The transition from conventional methods of farming to ecological ones contains risk (Serra, Zilberman and Gil, 2008). Risk perception plays a key role in defining an ambiguous risk issue (Regan, 2019). Social and behavioural scientists have conducted research over the last few decades that exhibits that risk is a phenomenon which originates in the human mind and which is influenced by subjective beliefs, values and social and cultural settings (Regan, 2019, p.2). Economics has tried to have a unifying approach to decision making and decision under uncertainty (Gilboa and Marinacci, 2016). No modeling approach can predict human behavior, nonetheless, EUT has been considered good enough to study the risk taking behavior by farmers and other decision makers (Hardaker and Lien, 2010).

EUT deals with the choice among acts where the decision-maker is not aware which consequence will result from a chosen act (Eatwell, Milgate and Newman, 1990). Daniel Bernouli (1738, cited in Eatwell, Milgate and Newman, 1990, p.70) is considered to be the founder of the Expected Utility framework. In EUT a decision-maker chooses the action with the highest expected utility, where the expected utility of an action is the sum of the products of probability and utility over all possible consequences (Eatwell, Milgate and Newman, 1990). The EUT framework has three components: the possible outcomes, the likelihood of possible outcomes, and the utility (or desirability) of possible outcomes (Hurley, 2010). In EUT the evaluation of a decision and action depends only on its probability distribution over the consequences instead of functions from the states to the consequences (Eatwell, Milgate and Newman, 1990). The principles of EUT are elegant and tractable (Gilboa and Marinacci, 2016).

The EUT is applicable to choices involving other attributes, e.g., quality of life or the number of lives that could be lost or saved as a consequence of a policy decision (Kahneman and Tversky, 1979). The advantage of the EUT is the distinction it makes between risk exposure and risk preferences through the use of probabilities and a utility function (Chavas, Chambers and Pope, 2010 cited in Bocquého, Jacquet and Reynaud, 2014, p.136). Despite the fact that Agricultural Economics has some advantage (extensive data and comparable price distributions) regarding the suitability and the use of model risks like EUT, (Buschena, 2003). The EUT still has disadvantages when it is applied to the agricultural framework (Hurley, 2010).

The laboratory violations of the axioms of EUT have created doubts about the credibility of the method (Just and Peterson, 2010). First, according to Allais (1953, cited in Bocquého, Jacquet and Reynaud, 2014, p.136) economic agents do not behave according to the assumptions of the EUT. According to Kahneman and Tversky (1979) there are violations of independence, violations of descriptive and procedural invariance and dependence of the source of uncertainty. Moreover, the EUT has limits when it is applied to unique decisions, because it cannot help to determine the available decision choices and it is also cast in a timeless setting, limiting the potential to deal with real decision issues (Backus, Eidman and Dijkhuizen, 1997). Another problem with EUT is the absurd degrees of risk aversion, which may not be accurate pictures of actual risk behavior (Just and Peterson, 2010). In addition, EUT lacks consideration of any reference dependence and of probability weighting (Gonzalez-Ramirez, Arora and Podesta, 2018).

EUT deals with the adoption process as a procedure where economic agents maximize their Expected Utility, while the psychological behavioural models (TRA, TAM, TPB and DIT) study the psychological components of the human behavior that lead farmers to adopt a farming technology. Moreover, these psychological components can be associated with the EUT, since people try to maximize their Expected Utility and they do it by processing the information they receive from their environment. Attitude, social norms and the perspective for their control over the behavior are elements that form the information that economic agents receive, and due to this information they act accordingly in order to maximize their utility.

2.5 The functionality of behavioural models and EUT

According to Giannoccaro, Prosperi and Zanni (2010) researchers have to study more the technological methods that farmers may decide to adopt. From the above psychological theories (TRA, TAM, TPB and DIT) we can deduce the basic factors that can influence farmers to transit from conventional methods of farming to ecological ones. However, the axioms of EUT can be challenged (De Palma et al., 2008). According to De Palma et al. (2008) there are two ways to deal with this problem. The first is the use of non-expected utility theories and the best known method is the prospect theory and the second way is the use of non-deterministic methods, the most well-known is Random Utility Models (RUM) (De Palma et al., 2008). According to McFadden (2001) Random Utility Models (RUM) are successful because they combine empirical tractability and can give answers to a broad array of policy questions, where these answers are linked with the economic theory of consumer behavior. RUM is a subset of the class of probabilistic choice models and psychologists were the first to develop them in order to characterize observed inconsistencies in patterns of individual behavior (Manski, 1977). Later, economists began to use these models as an econometric representation of maximizing behavior (Manski, 1977). According to Manski (1977) in the RUM framework utilities are treated as random variables to represent a lack of information regarding the attributes of alternatives and/or decision makers on the part of the observer. Random Utility Theory (RUT) is the basis for the analysis of the choices through Discrete Choice Experiments (DCE) (Hoyos, 2010).

It is important to take into account the attitude, the social norms and the behavioural control of farmers for ecological farming technologies. Based on these factors, farmers decide which farming technology to use in order to increase their utility. In addition, it is important to examine whether incentives from the state (e.g. educational programmes about new farming technologies, funding, low tax rates, extension services) can facilitate the adoption and the continuance of usage of ecological farming techniques from farmers. This information can be linked with the behavioural models since the intervention of the state can affect the adoption of a new farming technology.

2.6 Conclusion

The reason we study the psychological behavioural models for the adoption of a technology and EUT is because we want to compare the methodologies with the DCE method, when it is used for studying the adoption of new ecological farming technologies. Choices of individuals are influenced by habit, experience, peer pressure, environmental constraints, household and family constraints, etc. (Louviere, Hensher and Swait, 2000). This set of influences affect farmers to adopt and continue ecological farming technologies. Behavioural models can provide the factors for the adoption of a new farming technology. However, the behavioural models do not include the variety of the hypothetical scenarios for the use of new technologies the way DCE do. Additionally, EUT axioms do not always hold, so the results of the method are not always credible (Just and Peterson, 2010). DCE includes hypothetical scenarios, which help researchers and policy makers to think and study potential policies and their outcomes to deal with uncertainty in the Agricultural field. The psychological behavioural models can function as complementary tools to DCE and help researchers to approach the adoption process for a new farming technology taking into account the attitude, the social norms and the perceived behavioural control. In this way researchers can obtain adequate information in order to structure their surveys, which is a part of the DCE, in the most efficient way and obtain the required information regarding the adoption of new ecological farming technologies. By obtaining the required information (through the collection of data from surveys), researchers can conduct analysis and study the adoption process of new ecological farming technologies with the use of DCE.

It is commonly accepted the disadvantage of the unobservable factors is they cannot be quantified and modelled properly. However, these factors affect the decision process for the adoption or not of ecological farming technologies and they should be taken into consideration. Fortunately, advancements in quantitative methods have provided ways to incorporate unobservable factors into adoption research methods. In this way a more holistic approach can be provided by researchers to policy makers when it comes to the adoption process of ecological methods of farming. The theoretical models for the adoption of a new technology lack suitable quantitative illustration, but they are a good start to depict unobservable factors and study them. In this way, the modeling of unobservable factors is improved and the methodologies for the adoption of ecological agricultural technologies are enhanced and provide more credible analysis.

3. Discrete Choice Experiments and Hybrid Choice Models

3.1 Introduction

There is an increasing interest for the environment and its monetary evaluation and potential policies from a social perspective to deal with pollution (Faccioli et al., 2020). Researchers use stated preference methods to measure people's willingness to pay (WTP) for environmental issues (Faccioli et al., 2020).

The natural ecosystem is a non-market good and its value cannot be based upon the production process, so we need non-market evaluation tools. Information regarding economic value upon the environment and surrogate markets for the values of ecosystem services are not available (Faccioli et al., 2020). According to Bateman et al. (2002) there three types of types of economic evaluation: revealed preference (RP), stated preference (SP) and benefits transfer (BT), which depend on estimates from RP and SP studies. Another use of Stated choice experiments is to study the behaviour of the population with regard to non-existent good or service (Gordon, Chapman and Blamey, 2001).

The aim of the Choice Modelling is to model the decision process of an individual or a group through stated preferences made in a particular context (Bateman et al., 2002). Choice Modelling includes some Stated Preference techniques, which value non-market goods (Bateman et al., 2002). Such techniques are: 1) choice experiment, 2) contingent ranking, 3) contingent evaluation, 4) paired comparisons (Bateman et al., 2002). Choice Experiments belong to the larger group of Choice Modelling Methodology (Bateman et al., 2002). Discrete Choice Experiments (DCE) method is often chosen and considered the most suitable scientific tool for studying the adoption of ecological farming technologies because DCE is theoretically based on Lancasterian Theory (Lancaster, 1966) and econometrically on Random Utility Models (RUM) (McFadden, 1973) and we can examine which factors affect the attitude of farmers for adopting or not ecological farming technologies from the economic perspective. More specifically, DCE helps researchers to include an economic framework which contributes significantly to the procedure of the evaluation (Louviere, Hensher and Swait, 2000).

Discrete choice experiments is a method in which respondents choose between mutually exclusive alternatives (Louviere, Hensher and Swait, 2000). The advantage of DCE is they are linked with action theories (Liebe et al., 2021). In addition, DCE can identify key factors of decision making, the acceptance of policies and heterogeneity in decision rules (Chorus, 2014).

More specifically the theory of Lancaster states it is the attributes of a good which increase/maximize the utility of a consumer and not the good on its own (Lancaster, 1966). The assumptions of the Lancasterian approach are: first, the characteristics of an economic good increase the consumer's utility; second, many characteristics are contained in one economic good and observed in many goods; third, independent economic goods may have characteristics different from those which are combined (Lancaster, 1966).

Lancaster's model can predict and explain human behaviour better by regarding differentiated goods, risk, advertising and generally Consumer's behavior and preferences because it allows multidimensionality (Lancaster, 1966). As a result, it is beneficial for the field of Economics, because it has created a path for the study of tradeoffs among economic activities. The Theory of Lancaster contributes to the non-market evaluation of goods and it is useful for the application of the DCE methodology.

Additionally, DCE is based econometrically on Random Utility Models (RUM) (McFadden, 1973). The analytical framework of the choice experiment data is based on Random Utility Theory, which assumes that a representative individual is rational and, in a given choice situation, selects the alternative that yields the highest level of utility (McFadden, 1973).

Thus, the Random Utility Theory (RUT) is a method to obtain conventional demand curves (Bateman et al., 2002). The representation of an economic agent's preferences is depicted through the following Utility Function:

The quantity of market goods is $X = 1...m$ and the quantity of the environmental good is $Z = 1...n$. The usual way to depict this model is into its deterministic and its error term $U = U\left(X_1...X_m; Z_1...Z_n\right) = V\left(X\right) + e\left(X, Z\right)$ (Bateman et al., 2002).

As a method of data collection, researchers intend to administer a questionnaire (choice sets) to farmers to inquire about which factors motivate them to transit from conventional to ecological technology technologies. Revealed preference data is not always possible to obtain, they can be expensive to collect, the economic good which is studied is not traded in the real market, revealed preference data depict the world as it is now and do not take into account hypothetical scenarios (Louviere, Hensher and Swait, 2000). On the other hand, Stated Preference Data can be very useful because they can include hypothetical scenarios and they can provide multiple information for every respondent (Louviere, Hensher and Swait, 2000). So, it is important for researchers to have some evidence in order to know how to approach the transition from conventional to ecological farming techniques.

The advantage of the Choice Experiments DCE is they can use both hypothetical and realistic scenarios for economic agents, and create alternative cases for the affected good and the policy of interest (Louviere, Hensher and Swait, 2000; Vega and Alpízar, 2011). However, this technique has limitations, which have to be taken into account (Bateman et al., 2002). An additional advantage of DCE is that it allows to disentangle the contribution of each of the attributes of the economic good or service to overall utility (Regassa, Abate and Kubik, 2021).

This method is useful for estimating the welfare measures for the sustainability of several features of natural ecosystems, including the willingness to pay and the consumer surplus for the transition to ecological methods of farming. Furthermore, outcomes of the choice experiments make a strong case for differentiating incentives for spreading environmental friendly technologies (Jaeck and Lifran, 2009).

DCE is a good method to deal with the shortcomings of the use of cross-sectional and longitudinal data (Regassa, Abate and Kubik, 2021). DCE gains increasingly popularity to elicit preferences for attributes of differentiated goods and services (Regassa, Abate and Kubik, 2021).

3.2 Weaknesses of DCE

However, like any research method, so does the DCE method have its weak points. The estimation of the value of an environmental good through Choice Experiments demands the assumption that the value of the whole is equal to the sum of the parts (Bateman et al., 2002). The welfare value estimates (from the Choice Experiments) depend very much on the study survey design (Bateman et al., 2002). The participants in the survey may have problems with the choice/rank complexity (Bateman et al., 2002). Choice Experiments method has more problems (in comparison with the contingent valuation) for the valuing of a series of tools, which are used by a policy maker (Bateman et al., 2002).

The methodology has been developed and improved through years to deal with these issues and the information it provides to policy makers is useful. In order for the evaluation methods to improve, they need to incorporate and represent human preferences better (Faccioli et al., 2020).

3.3 Developments in DCE

When it comes to farmers' decisions of new technology adoption, many researchers use a simple dichotomous variable approach (Mwangi and Kariuki, 2015). Although, this approach is necessary, it is not sufficient, because the dichotomous response reflects the status of awareness of improved technology rather than the actual adoption (Jain, Arora and Raju, 2009). Different scientific quantitative methods have been used and improved, and DCE is among them. DCE improves on and allows estimation of a consistent marginal rate of substitution for both existing and prospective traits (Hensher et al., 2005; Louviere, Hensher and Swait, 2000; Train, 2009).

The DCE technique has been developed and it can provide credible results for planning and implementation of policies. Chiew and Daziano (2016) propose another way to modify the parameters to WTP space, so that the welfare improvements are assessed differently in the methodology of choice modelling. They normalize the scale and the marginal utility of income (λ) is fixed. By substituting $\lambda = 1$ the utility function is modified directly into a consumer-surplus function and WTP is depicted directly (Chiew and Daziano, 2016). Using the Gibbs sampling framework, priors do not need to be defined on unidentified parameters, identify priors are not needed either (Chiew and Daziano, 2016).

Swait, Argo and Li (2018) incorporate the goals in a model and they do not include attributes, but they focus on goals they want to fulfil by choosing the suitable attributes. This is good for policies, because it is possible to plan and apply the suitable policy (Swait, Argo and Li, 2018).

Dellaert et al. (2018) claim the choices are a matter of goals and not attributes, they incorporate the goal-theme into their econometric model for better analysis. It is a usual mathematical programme with a ~~"side"~~ 'side' constraint, in their case the income constraint (Dellaert et al., 2018).

3.4 Presentation of HCM

Choice Modeling and DCE are flexible and can integrate theories from other social sciences (such as Psychology) and link with them (Liebe and Meyerhoff, 2021). Choice Modeling uses the controversial assumption of rationality, nonetheless, it is flexible enough to incorporate different decision rules and link with other Social Sciences (Liebe and Meyerhoff, 2021).

Moreover, there is criticism for Stated preference methods, because they do not take into account complex psychological and sociological factors in the evaluation of environmental goods and services (e.g. environmental attitudes) (Costanza et al., 2017; Faccioli et al., 2020). Liebe and Meyerhoff (2021,p.10) state: “A common critique of choice modelling in the social sciences is that these models are too simple in the sense that they cannot capture complex social context effects, sequential decision-making processes, as well as joint decision-making processes.”

It is commonly accepted traditional methods used to study and model the users’ choice behaviour may ignore the numerous non-quantitative factors that may affect users’ perceptions and behaviours (de Luca and Di Pace, 2017). De Luca and Di Pace (2017) claim psychological factors, such as attitudes, concerns and perceptions may affect user’s behaviour and they should be modelled.

According to McFadden (2001) human preferences and values are also influenced by unobservable factors, such as attitudes, perceptions or beliefs. These factors can enhance the explanatory power of valuation models, since they explain further preferences and heterogeneity among individuals (Ben-Akiva et al., 2002). Moreover, de Luca and Di Pace (2017) claim the adoption of a new technology is affected by factors, which depend on behavioural components.

Hybrid Choice Models (HCMs) (or integrated discrete choice latent variable models) can integrate latent constructs that include/contain concepts such as values, attitudes, norms and perceptions (McFadden, 1986). The starting point for HCMs is the work of Walker and Ben-Akiva (2002), then Ben-Akiva et al. (2002) presented the progress and the problems of HCMs. HCMs have become a trend (Chorus and Kroesen, 2014). More specifically in the field of transportation many experts have developed and tested models HCMs (Chorus and Kroesen, 2014,p.217). The main idea is choice models can integrate latent attitude-and perception- related variables and provide more behavioral realism and better information with regard to travel demand policies (Chorus and Kroesen, 2014). The integration of latent variables (unobservable variables, e.g. attitudes and perceptions) in choice models may depict better the human behaviour and lead to better transportation demand policies (Chorus and Kroesen, 2014).

In addition, HCMs can adjust the methodological differences among Social Sciences by combining the factor analytic approach used by social scientists with DCMs used by econometricians (Vij and Walker, 2016). This occurs because HCMs can incorporate psychometric data and latent constructs within existing representations of the decision-making process, dealing with any problems from the assumptions of previous models (Vij and Walker, 2016).

3.5 Latent Variables

There are significant concepts in the behavioural sciences which cannot be measured directly, such as knowledge, ambition, or personality (Walker and Ben-Akiva, 2002). Additionally, these concepts are not well defined and are named latent constructs (Walker and Ben-Akiva, 2002).

According to Schuster and Yuan (2005,p.1) latent variables are unobservable factors that determine the values of the observed variables significantly. Researchers include latent psychological constructs (e.g. attitudes and perceptions) into choice models and they study the benefits they get from them (Ben-Akiva et al., 2002).

Latent constructs cannot be measured directly, so special methods have been developed to infer information about them (Walker and Ben-Akiva, 2002,p.310). The assumption of these methods is even though the latent construct itself cannot be observed, its effects on measurable variables (called indicators) are observable and such relationships provide information on the underlying latent variable (Walker and Ben-Akiva, 2002,p.310). The intention is the Generalised Model to explicitly incorporate these behavioural factors, such as attitudes and perceptions, affecting the utility by modeling them as latent variables (Walker and Ben-Akiva, 2002,p.310).

According to Ben-Akiva et al. (2002) attitudes and perceptions of agents are key factors that can define the human behaviour. The way latent and observable variables are connected is "the observable explanatory variables, including characteristics of the individual (e.g., socio-economics, demographics, experience, expertise, etc.) and the attributes of alternatives (e.g., price) are linked to the individual's attitudes and perceptions through a causal mapping" (Ben-Akiva et al., 2002,p.14). Since attitudes and perceptions are unobservable to the analyst, they are represented by latent constructs (Ben-Akiva et al., 2002). Environmental psychology and sociology literatures have studied environmental attitudes and identity beliefs on behaviour are among the most important factors explaining people's support for environmental conservation (Fielding, McDonald and Louis, 2008; Gatersleben, Murtagh and Abrahamse, 2014; Stets and Biga, 2003).

According to Ben-Akiva et al.(2002) perceptions are the beliefs or the estimates of agents for the levels of attributes of the alternatives. Perceptions can explain part of the random component of the utility function through unobserved attributes of agents (Ben-Akiva et al., 2002).

The latent variable attitude refers to the characteristics of the decision-maker (Ben-Akiva et al., 2002). Attitudes come from needs, values, tastes, and capabilities of agents (Ben-Akiva et al., 2002). In addition, attitudes are formed over time and are affected by experience and external factors that include socioeconomic characteristics (Ben-Akiva et al., 2002). Attitudes can explain unobserved individual heterogeneity, such as taste variations, choice set heterogeneity and decision protocol heterogeneity (Ben-Akiva et al., 2002).

According to de Luca and Di Pace (2017,p.1) :

> Attitudes are users' specific characteristics, and may allow to better interpreting the incidence of socio-economic and/or qualitative attributes in the decision process to adopt or not adopt a new technology.

In addition, Bahamonde-Birke et al. (2017) claims that attitudes are 'individual-specific' latent attributes which are constant across choice alternatives. Nonetheless, perceptions are ‘alternative-specific’ latent attributes and vary across choice alternatives (Bahamonde-Birke et al., 2017). Bahamonde-Birke et al. (2017) noticed perceptions may have an impact on the decision making process and both perceptions and attitudes may explain variability among agents.

According to Walker and Ben-Akiva (2002,p.340) with the incorporation of latent variables, choice models can include more realistic choice procedures and enable the validity of more parsimonious structures to be tested. The reason is latent constructs enhance the behavioural representation of the choice process and the inclusion of taste heterogeneity improves the explanatory power of the model (Ben-Akiva et al., 2002). Generally, social Contexts affect behaviour and decision making (Bruch and Feinberg, 2017). By including the impact of attitudes and other psychological constructs the study of human behaviour can be enhanced (Amaris et al., 2021). In this way more credible results can be provided by research and adoption technology programmes can be implemented more efficiently.

3.6 HCM, the mathematical framework

According to Abou-Zeid and Ben-Akiva (2014,p.383):

> The Hybrid Choice Model (HCM) is a modeling framework that attempts to bridge the gap between discrete choice models and behavioral theories by representing explicitly unobserved elements of the decision-making process, such as the influence of attitudes, perceptions and decision protocols. It integrates discrete choice models with latent (or unobserved) variable models.

The purpose of HCM is to integrate a behavioural approach to develop predictive choice models further and go beyond random utility models (RUM) (Ben-Akiva et al., 2002). HCMs can combine expertise from different research fields to improve choice modeling application (Liebe and Meyerhoff, 2021). Researchers have expressed a strong interest in HCMs to explain heterogeneity, with applications in different research fields, like sociology (Liebe and Meyerhoff, 2021,p.7). Values, attitudes, norms and perceptions are fundamental components of Sociology and Psychology, including the development of suitable survey-based measurement tools (Liebe and Meyerhoff, 2021). Suitable statistical choice models can incorporate sociological and psychological constructs (such as values, attitudes, norms and perceptions) in the fields of transportation and agri-environmental economics (Liebe and Meyerhoff, 2021). For example, Czajkowski, Hanley and Nyborg (2017) use a hybrid logit model to show how economic factors affecting the net costs of recycling; personal moral sentiments; and social pressures can affect an agent on how much to recycle. Nonetheless, factors such as values, attitudes, social and personal norms, and perceptions have different definitions across the social sciences and corresponding theories exist across the social research fields (Liebe and Meyerhoff, 2021,p.7).

Faccioli et al. (2020) conduct a DCE exercise by including general environmental attitudes and place identity beliefs. Faccioli et al. (2020) manage to provide better understanding for preference heterogeneity by providing better preference and welfare measure estimates. In this way better environmental policies can be planned and implemented (Faccioli et al., 2020). Apart from environmental attitudes and place identity beliefs, valuation literature has not studied factors, such as social norms, people's awareness, subjective perceptions or cognitive elements extensively (Faccioli et al., 2020). Nonetheless, environmental psychologists and sociologists consider these factors important (Faccioli et al., 2020).

However, the decision making process in new choice contexts may be affected by both ‘utilitarian’ and non ‘utilitarian’ attributes such as users’ emotion, perceptions and beliefs (De Luca and Di Pace, 2017 cited in de Luca and Di Pace, 2017,p.1).

According to Walker and Ben-Akiva (2002) by using extensions, choice models can incorporate latent variables and include more realistic choice procedures and enable the validity of more parsimonious structures to be tested.

Researchers have developed many extensions to improve RUM so that the choice behaviour can be predicted (Ben-Akiva et al., 2002). These enhancements are integrated in the general HCM by relaxing the basic RUM framework and enriching underlying behavioral characterizations with the incorporation of non-RUM decision protocols (Ben-Akiva et al., 2002).

According to Ben-Akiva et al. (2002,p.166) these extensions are:

- The addition of flexible disturbances (e.g., factor analytic) to mimic any desirable error structures (such as relaxing the IIA structure of logit or specifying random parameters).
- The explicit modeling of latent psychological factors such as attitudes and perceptions (latent variables). That is, combining ‘hard information’ (such as reasonably well-measured socio-economic characteristics) with ‘soft information’ on population heterogeneity (such as indicators for psychological characteristics that are difficult to measure, for example, risk attitudes, impatience, and self-control) in discrete choice models. The aim is to ‘explain’ seemingly irrational behavior, that is, model structurally using economic and psychological data, a substantial part of the unobserved heterogeneity.
- The inclusion of latent segmentation of the population (latent classes), which allows for different decision protocols including non-RUM, market segmentation, and choice set formulation.

It is significant to mention HCMs can incorporate non-RUM decision protocols, so the assumption of RUM is not needed (Ben-Akiva et al., 2002). If the model of interest is not RUM, then a paramorphic representation of non-RUM behavior can be used to depict the utility model, with the advantage of inference through the use of a statistical model (Ben-Akiva et al., 2002).

Additionally, there are advantages in using HCMs. According to Abou-Zeid and Ben-Akiva (2014) the first advantage is HCMs can model unobserved heterogeneity precisely, for example the dependence of taste parameters on underlying latent variables, like attitudes. The second advantage is latent variables provide additional information, which enhances the statistical efficiency of the parameter estimates (Abou-Zeid and Ben-Akiva, 2014). The third advantage is HCM depict the decision making process of people better, because HCM include observable and latent factors, while the usual DCMs include only observable variables (Abou-Zeid and Ben-Akiva, 2014). The fourth advantage is HCMs can provide better targeted policy measures, because they provide more sensible predictions and better market segmentation (Abou-Zeid and Ben-Akiva, 2014). In addition, de Luca and Di Pace (2017) claim HCMs study better phenomena for the adoption of a new technology and they may allow carrying out more realistic sensitivity analyses. HCMs could be more reliable solution for analysing environmental impacts on specific infrastructures and/or small urban areas (de Luca and Di Pace, 2017).

It needs to be taken into account that despite all factors/constructs can affect directly preferences and corresponding behaviour, a hierarchy starts with fundamental values (e.g. universalism) affecting general attitudes (e.g. environmental concern in our case) (Liebe and Meyerhoff, 2021). These fundamental values affect specific attitudes (e.g. attitudes ecological farming methods), as well as subjective norms (e.g. perceived social approval and moral obligation to adopt ecological farming techniques) towards a specific (choice) behaviour (e.g. choice between farming technologies options) (Liebe and Meyerhoff, 2021). The effects of constructs, like values and attitudes, can be stronger if indirect effects are taken into account too (Liebe and Meyerhoff, 2021). More specifically general attitudes can affect specific attitudes for a behaviour, which also affects stated preferences (Liebe and Meyerhoff, 2021). According to Ajzen (1991;2005) attitudes and behaviour should be measured at the same level of specificity due to the strong connection of attitude-behaviour and norm-behaviour. According to Liebe and Meyerhoff (2021) general constructs like attitudes and their direct and indirect effects should be taken into account through specific concepts on stated choice behaviour. For example, Borriello and Rose (2021) study the effects of general and specific attitudes in a stated choice experiment on train service. According to the results of their study both general and specific attitudes should be included as latent variables in the HCM (Borriello and Rose, 2021). Borriello and Rose (2021) explain that ignoring general and specific attitudes, especially the specific ones, would not fully indicate the psychological processes involved in choice-making and might lead to inconsistent estimates. Nonetheless, there are latent variables that are endogenous to the choice behaviour, such as attitudes and perceptions, because of learning effects and there are latent variables such as social norms and values that can be stable in the long-term and are much less likely to be affected by short-term behaviour (Vij and Walker, 2016).

HCMs provide a mathematical framework for studying and applying complex theories of behaviour and depict heterogeneity in quantitative terms (Vij and Walker, 2016). In addition, there are methods to control for endogenous variables in the field of Discrete Choice Models (DCM) (Vij and Walker, 2016).

3.6.1 HCM Framework

In the HCM framework there is the measurement relationship of the latent variable model and the structural relationship of the discrete choice model part (Kim, Rasouli and Timmermans, 2014). In both cases, linear-in-parameters model specifications have been used for these effects in the HCM framework (Kim, Rasouli and Timmermans, 2014). Nonetheless, linear effect is just one of all possible types of relationship, since a linear function is a special case of nonlinear functions (Kim, Rasouli and Timmermans, 2014). More specifically, for the latent attitudes, nonlinear effects of latent attitudes on the utilities have not yet been examined till today/recently (Kim, Rasouli and Timmermans, 2014). According to Kim, Rasouli and Timmermans (2014,p.29) "When the utility functions underlying the discrete choice model are assumed linear in parameters, the model cannot represent any varying marginal utility of the levels of the explanatory variables". When it comes to the latent variable attitudes, different levels can generate a different marginal utility (Kim, Rasouli and Timmermans, 2014). In addition, if a HCM does not take into consideration nonlinear relationships, it may provide biased policy effects (Kim, Rasouli and Timmermans, 2014). However, according to Kim, Rasouli and Timmermans (2014,p.29) "there is no general approach to deal with nonlinear relationships related to latent variables in discrete choice analyses.". So, it is essential to relax the linearity assumption and check for any nonlinearity in the utility functions of HCMs so that the more general choice behaviour can be depicted (Kim, Rasouli and Timmermans, 2014).

There are some ways to allow nonlinearity in the utility functions (Kim, Rasouli and Timmermans, 2014).The first method is linear-in-parameter specifications (Kim, Rasouli and Timmermans, 2014). This method can be applied through the use of piecewise linear functions by segmenting the attribute levels, so different parameters for different attribute levels can be obtained (Kim, Rasouli and Timmermans, 2014). A nonlinear utility function can be approximated through these segmentations (Kim, Rasouli and Timmermans, 2014). The other way is to calculate new values for variables by using predetermined nonlinear functions such as logarithmic, exponential or power functions (Kim, Rasouli and Timmermans, 2014).

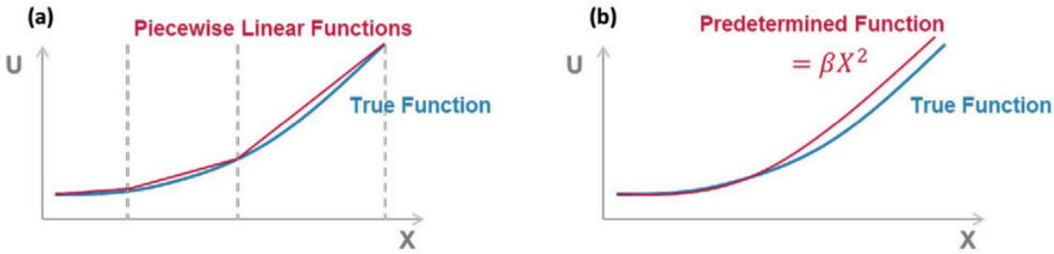

Figure 1: Approximation of nonlinear function based on linear specification: (a) using piecewise linear functions; (b) using a predetermined function (Kim, Rasouli and Timmermans, 2014, p.30).

The first method has some limitations though (Kim, Rasouli and Timmermans, 2014). Researchers need to predetermine functional form, the number of piecewise linear functions and range of each segment, so it is difficult to choose the ideal model to depict nonlinear relationships in the data (Kim, Rasouli and Timmermans, 2014). In addition, there is no diagnostic test to verify which functional form is more suitable and (Kim, Rasouli and Timmermans, 2014).

The second method is the functional form for each variable can be decided endogenously through the estimation result (Kim, Rasouli and Timmermans, 2014). Moreover, a statistical diagnostic test can be carried out in this method (Kim, Rasouli and Timmermans, 2014).

The different types of models into the discrete choice analysis enhance the HCM framework to account for heterogeneity across decision makers, because of the different latent variables (Kim, Rasouli and Timmermans, 2014). In addition, the incorporation of the social influence variables into the utility function of discrete choice model allows HCMs to take into consideration peoples' interdependent traits stemming from peoples' sociality (Kim, Rasouli and Timmermans, 2014). The non-linear specifications for the utility functions help HCMs to study nonlinear effects of latent variables (Kim, Rasouli and Timmermans, 2014). Through these developments the HCM methodology is improved and it can study the choice behaviour of agents much better (Kim, Rasouli and Timmermans, 2014).

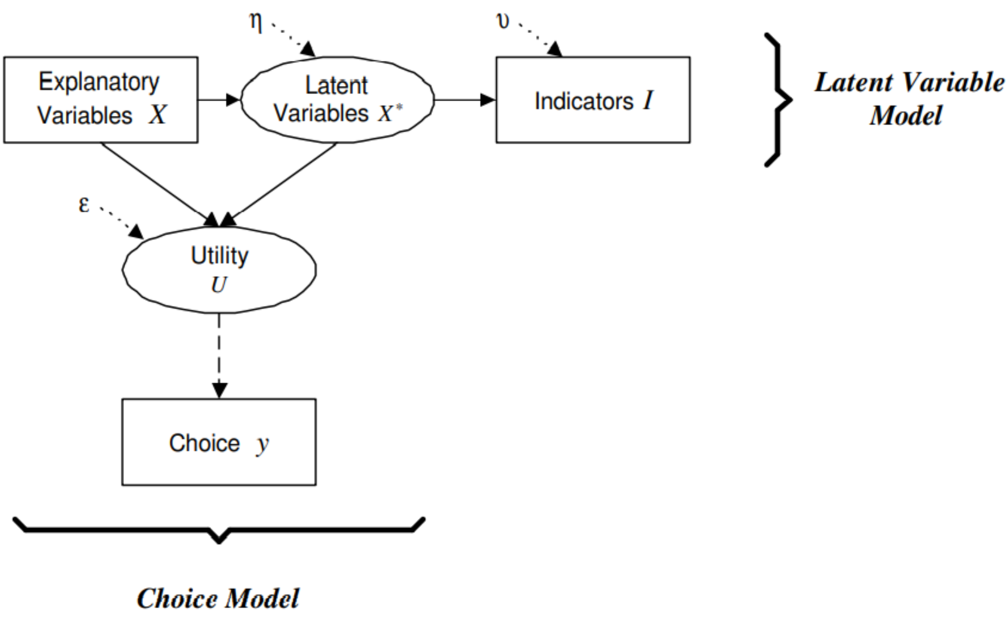

Figure 2: Integrated Choice and Latent Variable Model (Ben-Akiva et al.,2002,p.6).

The model consists of a choice model and a latent variable model (Walker and Ben-Akiva, 2002). The presented model has both observable and non-observable explanatory variables (Walker and Ben-Akiva, 2002). According to Walker and Ben-Akiva (2002) X_n^* depicts the unobservable explanatory variables, and the utility equation for the choice model is :

$$U_n = V\left(X_n, X_n^*; \beta\right) + \varepsilon_n. \qquad (3.1)$$

Given the latent variables, the probability of y_n conditional on X_n^* would be:

$$P\left(y_n \middle| X_n, X_n^*; \beta, \theta_\varepsilon\right). \qquad (3.2)$$

This probability needs to be integrated over the distribution of the latent variables to obtain the unconditional probability of interest. This requires the latent variable structural model:

$X_n^* = X^*\left(X_n; \lambda\right) + \omega_n$, this structural model describes the latent variable X_n^* as a function of observable explanatory variables X_n, a set of parameters λ and a disturbance $\omega \sim D\left(\theta_\omega\right)$. As a result of this equation, the density function of the latent variables, $f\left(X^* \middle| X_n; \lambda, \theta_\omega\right)$, is obtained and the unconditional probability equation is:

$$P\left(y_n \middle| X_n; \beta, \lambda, \theta_\varepsilon, \theta_\omega\right) = \int P\left(y_n \middle| X_n, X^*; \beta, \theta_\varepsilon\right) f\left(X^* \middle| X_n; \lambda, \theta_\omega\right) dX^*. \qquad (3.3)$$

It is difficult to estimate this model based on the observed preference indicator alone and so psychometric data, such as responses to attitudinal and perceptual survey questions, are used as indicators of the latent psychological factors. The latent variable measurement equation incorporates psychometric data I_n :

$I_n = I\left(X_n^*;\alpha\right)+\upsilon_n$, where these psychometric data are described as a function of the latent variables X_n^*, a set of parameters α and a disturbance $\upsilon_n \sim D\left(\theta_\upsilon\right)$. From this equation, the density function of the indicators, $f\left(I_n \middle| X^*;\alpha,\theta_\upsilon\right)$, is obtained. With the incorporation of the density function of the indicators into the likelihood leads to the final form of the integrated choice and latent variable model (Walker and Ben-Akiva, 2002):

$$P\left(y_n, I_n \middle| X_n;\beta,\alpha,\lambda,\theta_\varepsilon,\theta_\upsilon,\theta_\omega\right)=\int P\left(y_n \middle| X_n, X^*;\beta,\theta_\varepsilon\right) f\left(I_n \middle| X^*;\alpha,\theta_\upsilon\right) f\left(X^* \middle| X_n;\lambda,\theta_\omega\right) dX^*. \tag{3.4}$$

3.7 Conclusion

HCMs as every research methodology does not come without limitations and problems. By including new behavioural factors for the improvement of the environmental evaluation field, new challenges may arise (Faccioli et al., 2020). According to Faccioli et al. (2020) budget and time constraints may challenge the collection of data for psychological and sociological aspects for the environment and more advanced econometric tools and programming code may be needed for the incorporation and analysis of such psychological and sociological constructs. Moreover, Abou-Zeid and Ben-Akiva (2014) also claim the lack of econometric tools and programming language as one of the problems of estimating HCMs. Another problem of HCMs is the structural equations of the latent variables usually have low explanatory power in most empirical applications as usually indicated by insignificant variables and low pseudo R^2 (Abou-Zeid and Ben-Akiva, 2014). Third problem with HCMs is endogeneity (Abou-Zeid and Ben-Akiva, 2014). If the choice has an impact on the attitude which is not modeled, the parameter estimates will be biased (Abou-Zeid and Ben-Akiva, 2014). The fourth problem lies on the application of HCMs, more applications need to be adopt HCMs in order to check the validity of these models (Abou-Zeid and Ben-Akiva, 2014).

Despite all these problems, according to Ben-Akiva et al. (2002) HCMs has showed that are promising, the goodness of fit improves, the latent variables are significant, and the behavioral representation is more satisfying. The improvements in the field of Econometrics have an impact on Choice Modelling and HCMs as well. With these improvements policy-makers can approach better the behaviour of economic agents regarding the adoption of farming technologies.

HCMs have not been used in the Agri-Environmental field extensively, so their effectiveness can be used in the adoption of ecological farming technologies. Additionally, according to Knowler and Bradshaw (2007) there is no universal factor explaining the adoption of ecological farming technologies, so HCMs can provide more insight regarding the factors for the adoption of ecological farming technologies. These models are promising and can still be the answer for incorporating non-observable behavioural factors when it comes to the adoption of a new ecological farming technology. HCMs can uncover the potential causal effects for the field of interest , in our case the adoption of ecological methods of farming (Liebe et al., 2021; Vij and Walker, 2016). In this way HCMs can used for studying the adoption of ecological methods of farming and provide useful information to policy-makers and stake holders with regard to the advantages and disadvantages of adopting ecological methods of farming.

4. Conclusions

The conclusions provide the last chapter of the thesis. A summary about the structure and main findings of the thesis are provided in the first section. In the second section we discuss the used method and the adoption factors. A third section informs the reader with regard to conclusions and recommendations. Finally, the chapter concludes by illustrating the limitations of the approach and the need for future research.

4.1 Summary of the thesis

Abandoning conventional methods of farming and adopting ecological ones is a hot topic nowadays. However, it is needed to know how to study the adoption of ecological farming methods in order to motivate farmers to use these techniques. And that was the motivation for this study.

The purpose of this thesis is to study the ways the adoption of ecological agricultural technologies can be studied. More specifically the research question we try to answer is:

How can the adoption of ecological agricultural technologies be studied?

This thesis contributes to the acknowledgement of the factors and the methodologies (e.g. DCE or HCM) for the adoption of ecological agricultural technologies. We present their advantages and disadvantages of the adoption factors and the methodologies. In this way researchers can know and explore a new ways on how to improve the existing methodologies, which can provide more information about the adoption of ecological agricultural technologies.

In the beginning, we present the most cited papers in three databases (Google Scholar, Scopus and Web of Science) regarding the adoption of ecological agricultural methods, as well as we present the most common adoption factors. After, in the second chapter we present the methodological frameworks for the adoption of new technologies used psychologists and economists. In the beginning of the second chapter we present the psychological theories and their variables and then we proceed with the framework of EUT. Our intention is to exhibit the advantages and disadvantages of the presented methodologies. In the third chapter we exhibit the DCE technique, as well as its weaknesses and its advancements. Moreover, HCMs, which are an extension of DCM, are presented. The fourth chapter concludes the thesis by illustrating the limitations of our approach and the future perspectives.

In order to study properly the adoption of ecological agricultural technologies, we need to take into consideration the proper adoption factors as well as the most suitable research methods. In the first chapter of the thesis we present the most cited published papers in three databases (Google Scholar, Scopus and Web of Science) regarding the factors farmers take into account in order to adopt ecological farming technologies. Also, we present the most common adoption factors based on the papers we present.

4.2 The Methodological Approach and the adoption factors

The applied methodological approach of literature review has been useful, since it answers our research question and provides additional insights into farmers' choice to adopt ecological methods of farming. The literature review method was chosen because it appeared to be a suitable tool for answering our research question.

It is commonly accepted the decision process of economic agents depends on both observable and unobservable factors. For this reason we study the most common adoption factors. More specifically, the adoption factors are usually divided into categories for the convenience of researchers and policy makers. The most usual categorization is economic, social and institutional factors (Akudugu, Guo and Dadzie, 2012; Melesse, 2018). In this thesis we study the social factors, the gender, the age, the education, the farm size, the income, the environmental conditions, off-farm income, the experience, the household size, the hired labour, the extension services, the economic factors, the profitability, the cost, the risk, the area, the expertise of the farm, the tenure, the environmental attitude and the social norms. The reason we study these adoption factors is because they appear the most in the articles we present.

4.3 Conclusions and recommendations

It is increasingly recognised that conventional technologies of farming contribute to high financial and environmental costs. Gliessman, Engles and Krieger (1998) claim the structure of conventional farming is based on the maximization of profit and the maximization of production. Nonetheless, in order to have these goals achieved, the undesirable effects of conventional farming are not taken into account. The basic elements of modern farming consist of six methods: intensive tillage, monoculture, irrigation, application of inorganic fertilizer, chemical pest control, and genetic manipulation of crop plants (Gliessman, Engles and Krieger, 1998). The great disadvantage of conventional farming is it provides high productivity in the present, but it sacrifices the future productivity, as a result of this there is great pressure on the ecosystem (Gliessman, Engles and Krieger, 1998).

Gomiero, Pimentel and Paoletti (2011) discover organic food and food security could be important to maintain the food security and decrease the environmental burden of the agricultural sector. Offermann and Nieberg (2002) mention the future of ecological/organic farming lies on consumers' willingness to pay for ecological farming. Ecological farms have to deal with the same problems as conventional farms do, such as climate conditions, agricultural policies and prices. The feasibility of the organic technology is an important factor for its adoption (Gomiero, Pimentel and Paoletti, 2011). Another perspective lies on the reforms in the Agricultural Sector and the transition to ecological methods of farming which can lead to serious reforms. Reforms in the agricultural sector are considered to be the fastest and the most efficient way to reduce poverty overall and deal with spatial economic inequalities especially in low-income countries (De Janvry and Sadoulet, 2010; Mellor, 2017; Spielman, Kelemwork and Alemu, 2012).

The natural ecosystem is a non-market good and its value cannot be based upon the production process, so we need non-market evaluation tools that are related to the Economic Theory. DCE are the most suitable quantitative scientific tool for analyzing the adoption of ecological methods of farming, since DCE technique is connected with the Lancasterian Theory and RUT and in this way researchers can examine which factors affect the attitude of farmers for adopting or not adopting ecological agricultural technologies from the economic perspective. So, that the social planner can design and apply policies more efficiently from the information he obtains.

Moreover, unobservable factors should be taken into account in the study and implementation of adoption technology programmes. Unobservable factors have a huge impact on the decision process for adopting a new farming technology. Unobservable factors cannot be studied properly by the usual DCMs, but HCMs can study them. HCMs are extension to DCMs and they can incorporate unobservable factors (e.g. attitude). It is an undeniable fact that HCMs are complicated econometric structures and demanding in software power and code, but they can offer a lot of insight in the field of adopting ecological methods of farming. In addition, HCMs have not been used extensively in the Agri-Environmental Field and there is a huge potential for their use in the field of farming technology adoption. For these reasons, we strongly suggest the use and development of HCMs in the adoption technology sector.

This analysis is important, because it puts more light on the decision process of choosing a farming technology and it can help farmers to be more aware about the costs and the benefits of ecological farming techniques. For these reasons it is essential to study what encourages farmers to adopt environmentally healthier methods of farming. Nonetheless, researchers should clearly state how they are defining technology adoption, so that they can develop appropriate tools to measure it (Mwangi and Kariuki, 2015). Clarity is important when it comes to policy programmes. In this way, both researchers and policy makers can plan and implement suitable adoption technology policies.

4.4 Limitations of the study and proposals for future research

Limitations of our research: Several limitations can be spotted in this study and further research should include additional aspects which are not studied here. We include the most cited papers regarding the adoption of ecological methods of farming, while there are other studies less cited that study the adoption of ecological agricultural technologies. We choose the most cited ones, because they provide more credibility regarding the adoption of ecological agricultural methods, as they are methodologically sound and published in peer journals. However, even the less cited papers can provide useful insight. The other limitation of our study is that it does not conduct empirical research to compare the DCMs and the HCMs techniques.

The following areas are identified for further research:

- The current study is a literature review on how the adoption of ecological agricultural technologies can be studied. Further empirical studies can be conducted, by studying the same ecological agricultural technology in different regions. In this way more light can be shed regarding the adoption factors for a specific ecological farming method. Therefore, a clearer view will be obtained which adoption factors are important and need to be taken into account by researchers and policy makers. Based on the attributes of the farming product and the attributes of the ecological farming technique of course (Mwangi and Kariuki, 2015).
- Use and compare both DCE and HCMs frameworks in studies for adopting a specific ecological farming method. Later, observe the adoption process of the ecological agricultural technology and compare which method has more accurate results. As a result, the credibility of the two quantitative methods can be tested and evaluated.

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