Are farmers willing to pay for bio-plastic products? The case of mulching films from urban waste

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Abstract

The adoption of mulching films containing substances derived from chemical treatment of urban and agricultural wastes (SBOs) can be considered, at the moment, a possible solution to pollution from the use of plastics in agriculture. This research aims to identify the factors influencing farmers' willingness to pay (WTP) for SBOs films. A survey was conducted in 2014 in the province of Foggia and involved a random sample of 107 horticultural farms. Econometric regression using Heckman's sample-selection model was performed. In line with the theory of the diffusion of innovation, findings show that the adoption of SBOs films is higher among farmers who already use the mulching technique; among them, those farmers using conventional films are willing to pay a premium price for the innovative films. In addition, findings show that durability and strength are relevant attributes positively affecting farmers' WTP.

Keywords: *biodegradable mulching film, willingness to pay, innovation, farmers' stated preferences.*

Résumé

L'adoption de films de paillage contenant des substances dérivées du traitement chimique des déchets urbains et agricoles (SBO) représente une solution possible à la pollution causée par l'utilisation de plastiques en agriculture. Cette recherche vise à identifier les facteurs qui influent sur le consentement à payer (CAP) des agriculteurs pour le film SBO. Une enquête a été menée en 2014 dans la province de Foggia (Italie) sur un échantillon de 107 entreprises horticoles. Les données recueillies ont été analysées par une régression économétrique basée sur le modèle de Heckman. Conformément à la théorie de la diffusion de l'innovation, les résultats montrent que l'adoption d'un film SBO est plus importante chez les agriculteurs qui utilisent déjà la technique de paillage. Parmi ceux-ci, les agriculteurs utilisant des films traditionnels sont disponibles à payer un prix plus élevé pour des films innovants. En outre, les résultats montrent que la durée et la résistance du film sont des attributs significatifs qui influencent positivement le CAP des agriculteurs.

Mots-clés: film de paillage biodégradable, consentement à payer, innovation, préférences des agriculteurs.

1. Introduction

The demand for bio-plastics is expected to grow quickly in the coming years. It is estimated that the global market for bio-plastics will grow at a rate of 20% per year (European Commission, 2011).

The replacement of plastics derived from petroleum with those obtained from renewable resources, such as biodegradable plastics, can be considered a possible solution to pollution from plastic use. While the plastic films are generally disposed of through landfills, incineration and recycling at the end of their life cycle, biodegradable materials can be integrated directly into the soil, where the bacterial flora turns them into carbon dioxide or methane, water and biomass.

The research in this area has recently focused on the development of materials and technologies to improve the mechanical properties as well as the biodegrability and the environmental compatibility of mulching films. Among these, the outcomes of the *Biochemenergy project* (funded by the local government of Piemonte region, Italy) demonstrated that urban and agriculture wastes may be chemically processed to obtain the so-called *soluble bio-organics substances* (SBOs) that may be used to manufacture several bio-based products and, among them, mulching films for agricultural uses (Montoneri *et al.,* 2011). The marketing and adoption of mulching films containing SBOs have a double positive impact, both economically and environmentally, by diversifying the range of products sold by the processing plant, contributing to the substitution of plastics obtained by fossil oil with those obtained from biomass and therefore contributing to the reduction of carbon dioxide emissions.

Despite these relevant arguments, the potential market of alternative bio-plastic products is poorly reported in the literature. This literature gap in the ex-ante assessment reports a scarce attention from investors and companies toward the development of this new business opportunity.

To evaluate the economic potential of such a bio-product, with particular reference to the use of bio-waste for the production of mulching films, our study proposes to elicit farmers' willingness to pay (WTP) for this product and provide a descriptive overview of market potential.

The first step in the search for value biodegradable mulching films from the SBOs market is to identify the factors affecting the adoption of mulching films and examine farmers' behavior towards innovations.

There is abundant literature addressing the adoption behavior in agriculture, which highlights the relevance of a range of personal, social, cultural and economic factors, as well as the characteristics of the innovation itself on the farmer's preferences (Hipple and Duffy, 2002; Henning *et al.,* 2003; Diederen *et al.,* 2003; Urama, 2006; Birol *et al.*, 2007, Jensen *et al.*, 2007; Prokopy *et al.*, 2008; Sherrington

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et al., 2008; Blasi *et al.*, 2011; Rossi and Hinrichs, 2011; Liu and Zhang, 2011; Aubert *et al.,* 2012; Ndonga and Mungatana, 2013; White and Self, 2013).

Some research has determined the impact of the sociodemographic factors, such as gender, age, education, income (Birol *et al.*, 2007; Solomon *et al.,* 2009; Bakopoulou *et al.*, 2010; Liu and Zhang, 2011; Tey *et al.*, 2014), factors related to farm characteristics such as size or cropping intensity (Liu and Zhang, 2011; Rossi and Hinrichs, 2011), environmental attitudes and awareness (Prokopy *et al.*, 2008), cropping intensity, social networks, and innovation attributes such as technical nature and economic impacts (Blazy *et al.*, 2011; Tey *et al.*, 2014). Indeed, the agronomic and economic benefits represent the most important factors that justify the fast diffusion of the technique in the world. Specifically, a number of studies (Martin-Closas *et al.,* 2003; Filippi *et al.*, 2011; Saraiva *et al.*, 2012; Moreno *et al.,* 2013; Haapala *et al.*, 2014; Costa *et al.*, 2014) have recently demonstrated that the mulching technique causes an increase in soil temperature, a weed pressure reduction, a moisture conservation, a reduction of certain insect pests, an increase of crop yields and a more efficient use of soil nutrients.

The economic benefits in terms of reduced costs resulting from water savings and reduced use of synthetic chemicals, such as pesticides or herbicides, make the adoption of this farming technique more convenient. In addition, mulching with biodegradable materials will save on labor costs as it is not needed for the removal of the films. Finally, the use of biodegradable films is one of the policy measures financed by the European Union under the Common Agricultural Policy (CAP) for the 2014-2020 period to compensate farmers for the increased costs that may result from the voluntary adoption of sustainable production methods.

Besides the technical and economic aspects, another determinant of innovation adoption is represented by the compatibility of the innovation with existing technologies (Tey *et al.*, 2014). The compatibility of an innovation, as perceived by the members of a social system, is positively related to its rate of adoption. In addition, previous practice provides a standard against which an innovation can be interpreted, thus decreasing its uncertainty. Any new idea is evaluated in comparison to existing practice (Rogers, 2005). The relevance and impact of the same variables on the individual's behavior are also examined on the topic of WTP value. Many studies (Hipple and Duffy, 2002; Birol *et al.*, 2007; Jensen *et al.*, 2007; Sherrington *et al.*, 2008; Bakopoulou *et al.*, 2010; Blazy *et al.*, 2011; Rossi and Hinrichs, 2011; Ndunda and Mungatana, 2013; Fewell, 2013; White and Selfa, 2013) show that sociodemographic factors, farm characteristics, environmental attitudes, social networks and innovation attributes represent the factors affecting WTP for agricultural and/or environmental innovation.

This large set of factors implied in the adoption process, put in light that the diffusion of an innovation is a complex issue, that is final adoption rates depend on the decision and interactions of a multitude of individual agents with their individual, rational-bounded, utility functions, that in turns reflect in their WTPs. Consequently, it is not to say that the way to successful innovation diffusion is to apply the formula that worked for previous innovation (Plsek, 2003). Past experience, coupled with advice from experts, can serve as a starting point, but an analytic breakdown of the specific issues related with the particular innovation under analysis is essential in order to succeed.

In this context, this research aims to investigate farmers' WTP for biodegradable films based on SBOs and to identify the most relevant factors influencing farmers' decision making. In particular, we focus on farmers' preferences for films' properties (i.e., strength, durability, mechanical harvesting and transparency) along with personal and socioeconomic features affecting the farmer's WTP. A survey was carried out in 2014 in the province of Foggia and involved a random sample of 107 horticultural farms. The methodology used to analyze the WTP function is the Heckman's sample-selection procedure, which includes a statistical two-phase approach to correction of the means.

The innovative aspect of this work is twofold. Firstly, since the potential market of alternative bioplastic products is poorly reported in the literature, it contributes to increasing the knowledge in this domain. Secondly, this work considers the biodegradable films derived from the valorization of biowaste instead of the conventional biodegradable films made of materials obtained from dedicated crops. One expected result is to breakdown the main aspects behind the individual decision process to tackle the complexity of diffusion issue.

The paper is organized as follows. Section 2 describes the methodology, econometric model and variables definition. Section 3 contains the case study and the survey structure. Section 4 deals with data description, empirical results and discussions. Finally, Section 5 ends with some concluding remarks.

2. Material and methods

2.1. Survey and sample

The method used for the WTP assessment is the contingent valuation method (CVM). The CVM aims at eliciting individuals' preferences, in monetary terms, for changes in the quantity or quality of goods through personal interviewing (Carson and Mitchell, 1995; Desvousges, 2012). Our analysis is based on data collected by means of a survey carried out in May 2014 in the province of Foggia. A detailed description of the sample was presented in Scaringelli *et al.* (2016). A total of 107 questionnaires were successfully completed through face-to-face interviews. The final sample included specialized horticulture farmers who already applied a mulching technique, whether biodegradable or conventional, as well as those farmers who currently do not apply any mulching at all. The questionnaire was structured in four parts. The first part aimed at collecting general information on the farms and farmers' socioeconomic characteristics, such as legal status, management type, land ownership, number of workers, crops pattern, environmental concerns, risk propensity, social networks and information channels. The second part is aimed at collecting information on the farmers' willingness to adopt biodegradable films derived from organic wastes. To identify the potential adopters of the innovative films, we separated farmers who already used the mulch from those non-users. In the first group, we divided the conventional from biodegradable users. The conventional adopters (first group - conventional) were asked if they would like to use a different material to cover the crops utilizing biodegradable films already on the market in place of the plastics. If they replied "yes", then we asked if they would be willing to use films containing SBOs. This question was also made to the biodegradable films' adopters (first group - users). We asked the non-users (second group) if they were willing to adopt the mulch as an agricultural practice; in case they replied "yes" we proceeded with the same questions posed to conventional adopters. In addition, we asked all those expressing negative feedback why they were practicing non-adoption. The choice of attributes and an auction simulation aimed at assessing farmers' WTP were included in the third part of the questionnaire. To identify the farmers' preferences for the films' properties, we asked farmers to sort five attributes according to a five-point Likert scale. The five attribute list, which was randomly proposed, included mechanical resistance during the stretch out of the film in the field (*strength)*, the possibility for mechanical harvesting of crops *(mechanical harvesting),* minor operations for the removal and disposal of the film at the end of the farming cycle (*disposal*), the entirety or durability of the materials compared to the crop duration *(durability)* and the higher soil warming capability through the use of light colors *(transparency).* After collecting information on the farmers' preferences to the films' characteristics, an auction simulation was carried out.

We chose these attributes based on the existing literature while during an in-depth interview with technicians the specific needs of the vegetable sector were found out. In doing this, we found that despite multiple benefits, the adoption of biodegradable mulch film is restrained, because its breakdown is generally premature in the field, decomposing before the end of the crop cycle (Kasirajan and Ngouajio, 2012). Therefore, durability could be of great relevance. On the other hand, the mechanical strength is a fundamental attribute, especially for less-thick biodegradable films, which need a perfectly level ground so that the material remains intact during the installation.

We supposed the existence, on the market, of organic waste-derived films, having similar properties to current biodegradable films in terms of quality and price (final cost, also considering the subsidies, of 450 €/ha provided a 1.80 m file distanced system). Then we asked the respondents how much they would be willing to pay for the same film with better performances (i.e., improved with the attributes they identified in the previous question).

Using the "interactive bidding" (IB) method to estimate WTP under CVM, a starting bid is provided to each farmer who expressed a willingness to adopt SBOs biodegradable film. If the farmers accept the first bid, two higher bids are offered. If they accept both higher bids, we ask for the maximum bid payable; otherwise, those values are considered to be the WTP. If the respondents reject the initial bid, then they are offered two lower bids. If the interviewees accept the lower bids, those values are considered to be the WTP. If the respondents reject the lower bids, we then ask to provide an estimate of the maximum amount they were willing to pay for the film. An example of an auction simulation can be found in Figure A1 in the Appendix.

Finally, the fourth and last part of the questionnaire was designed to obtain farmers' personal information such as gender, age, level of education and income.

2.2. Econometric regression

To underline the influential variables of WTP for biodegradable films from SBOs, we used Heckman's sample selection model. For the analysis of WTP, a simple linear OLS model is not adequate, as there may be a self-selection of the sample according to the farmers' adoption decision. This produces a selection bias that fails the random selection process assumed in the OLS regression. Consequently, WTP can only be observed for those farmers with the intention of adoption (Giannoccaro et al., 2017). The procedure first proposed by Heckman, which is performed in two stages, was applied. In the first stage, the respondent's decision to adopt or not to adopt is modeled, estimating the selection equation by a probit model. In the second stage, how much the respondents are willing to pay is modeled for all observations with an intention of adoption. The principal (or substantial) equation was estimated by OLS, including the selection bias correction factor (λ) as an additional independent variable.

In this study, the models are expressed as follows:

$$Z = \partial_0 + \partial_1 X_1 + \partial_2 X_2 + \partial_3 X_3 ...+ \partial_N X_N + \varphi \quad (1)$$

Equation (1) is the first-stage Heckman probit model. Z is the dependent variable, which represents the probability of SBOs films being adopted by farmers;
∂_0, ∂_1, ∂_2, ∂_3, ..., ∂_N, are coefficients that will be estimated while examining the factors affecting farmers' willingness to adopt, $X_1, X_2, X_3, ..., X_N$, are the explanatory variables and φ is the residual term.

$$Y=\beta_0 + \beta_1 X_1 +\beta_2 X_2 + \beta_3 X_3 + ... + + \beta_N X_N + \delta\lambda + \mu \quad (2)$$

Equation 2) is the linear regression model used in the second stage of our analysis. Y is the dependent variable, which is the farmers' WTP (i.e., monetary value). In the equation (2), the Mills ratio, λ, is added to overcome the sample selection bias. β_0, β_1, β_2, β_3, ... β_N, and δ are the coefficients to be estimated. X_1, X_2, X_3, ..., X_N, are the explanatory variables, and μ is the residual term.

More specifically, the explanatory variables can be grouped as follows: socioeconomic factors, agro-ecological factors and perceived films' attributes. In Table 1, all the variables are classified according to each group, while their description is reported below.

AGE indicates the farmers' age. The variable is expressed in quartiles. The expected relationship is negative. The underlying assumption is that the frequency of adoption is relatively higher among younger farmers; conversely, the age will decrease the possibility of adoption as a farmer's age increases, since the shift in technology means an uncertain practice to the old (Urama, 2006; Jensen *et al.*, 2007; Blazy *et al.*, 2011; Howley, 2012; Ozor *et al.*, 2013). In some studies (Yue *et al.*, 2010; Liu and Zang, 2011), the impact of age is not as expected, as it positively affects the adoption rate. *EXTJOB* is the off-farm employment. It indicates the decrease of the labor available on a farm and that the farmers are less likely to adopt a time-intensive practice. The negative relationship between the off-farm job and the adoption of agricultural innovation could be attributable to labor costs and in farm labor availability (Prokopy *et al.*, 2008; Howley, 2012). In addition, it has been claimed that off-farm employment may be related to farmers' attitudes towards new activities (Giannoccaro and Berbel, 2012). It is a dummy equal to 1 if the farmer is employed in another activity and 0 if the farmer works on the farm full time. *FAMLAB* indicates the number of family members employed in farming (including the conductor). The expected sign on the willingness to adopt is negative. The hypothesis is that the greater the number of family members working on the farm, the lower the cost for labor. Consequently, there is less propensity to adopt the mulch, as it is known that allows a saving in terms of labor. *SIZE* is represented by the hectares of irrigated land managed (lands owned and lands rented). This variable is used to measure the farm size, and it is included in quartiles. We expect the size of the farm to be positively associated with adoption, as larger farms have greater economies of scale (Urama, 2006; Jensen *et al.*, 2007; Liu and Zang, 2011; Blazy *et al.*, 2011; Ozor *et al.*, 2013). In addition, the adoption of a mulching technique can reduce irrigation water consumption, and, consequently, the greater the irrigated area, the greater the propensity to adopt the technique.

ROTCOV is related to the rotation crop for the last five years. From the literature, the rotation is included as a positive determinant of the adoption of the agricultural innovation to measure the farmers' environmental characteristics (Blazy *et al.*, 2011). Unlike previous works, we distinguish the simple rotation from the rotation with cover crops, for example, with the inclusion in the rotation of grassland green manure. The choice to include this variable in the model is explained by the fact that the rotation with a cover affects fertility, soil management and, to a greater extent, weed control. Consequently, if the farmer applies a rotation with cover crops, he would not need the mulch for weed control. The expected sign is negative. It is a dummy equal to 1 if the farmers use the biennial rotation with cover crops or intermediate and 0 otherwise (for example, biennial, three-year, quadrennial or other).

MULCH indicates the land hectares with mulches and is included as a proxy of the size. The WTP increases as the hectares of the soil with mulch are greater. Also, this variable measures the cost of the transaction to adopt the innovative films. If a farmer already uses the mulch (by conventional or biodegradable films), it is more likely he will adopt the innovation since transaction costs are expected to be lower. So, the expected sign is positive.

In equation 2, we include perceived attributes as positive determinants of higher WTP. We analyzed the relative advantage and the compatibility. Both attributes are perceived subjectively by those considering the adoption of innovation. Relative advantage describes the degree to which sustainable agricultural practices are seen as more beneficial than competing practices (Tey *et al.*, 2014). We measured the relative advantage by including two film attributes based on better technical performance on which respondents expressed their level of preferences: *DURABILITY* and *STRENGTH.* Both of the variables assume the following values: 2 if the attribute is perceived as essential or very important, 1 if the attribute is perceived as important or less important and 0 if the attribute is perceived to be unimportant or insignificant.

Table 1 - *Model variables.*

Variables (Code)	**Definition**	**Expected sign**
Socioeconomic factors		
X_1 *(AGE)*	Age groups <35 years 35-49 years 50-64 years ≥ 65 years	(-)
X_2 *(EXTJOB)*	Off-farm employment 1 if the farmer performs other activities in addition to agriculture	(-/+)
X_3 $(FAMLAB)$	Number of family members employed in farming (including the conductor)	(-)
X_4 $(SIZE)$	Farm size (Hectares of irrigated land - quartiles) <14 ha 14≤ ha ≤ 24 25≤ ha <69 ≥69 ha	(+)
Agro-ecological factors		
X_5 $(ROTCOV)$	Crop rotation (innovation attributes/technical nature) 1 if farmers make the biennial rotation with cover crops	(+)
X_6*(MULCH)*	Hectares of mulched land (quartiles) <1.7 ha 1.7≤ ha<3.5 3.5≤ha<14 ≥14 ha	(+)
Perceived attributes		
X_7 $(INTEGRITY)$	2 if durability is an essential or very important attribute 1 if durability is an important or less important attribute 0 if durability is an unimportant or insignificant attribute	(+/-)
$X_8$$(STRENGHT)$	2 if strength is an essential or very important attribute 1 if strength is an important or less important attribute 0 if strength is an unimportant or insignificant attribute	(+/-)
X_9 *(FILMTYPE)*	0 if the farmers don't apply mulching technique 1 if the farmers use the conventional films (in polyethylene) 2 if the farmers use the biodegradable films (in Mater-Bi)	(+)

Table 2 - *Number of potential adopters of SBOs films by type of farmers.*		
	No.	**Total (%)**
New potential adopters of SBO films	**64**	**60**
- Biodegradable film adopters	30	28
- Conventional film adopters	20	19
- Non-mulching technique adopters	14	13
Non-potential adopters of SBO films	**43**	**40**
- Biodegradable film adopters	3	3
- Conventional film adopters	19	17
- Non-mulching technique adopters	21	20
TOTAL	107	100

Source: Our elaborations.

Table 3 - *Rationales for non-willingness to adopt (% calculated on non-potential adopters of SBO films).*

Reason	**No.**	**Total (%)**
Non-willing to adopt mulching technique	**18**	**42**
- High cost of purchase and installation	12	28
- Difficulty for mechanical harvesting	5	12
- No adaptability to different types of soil	1	2
Non-willing to use biodegradable films	**22**	**51**
- Excessive soil preparation practices	2	5
- Rapid degradation	8	19
- Thinner than the conventional films	1	2
- High price	2	5
- Doubts about the agronomic performance	9	21
Non-willing to use SBOs films	**4**	**9**
- Doubts about the environmental and agronomic performance (moisture, duration, pollutants etc.)	4	9
Sample (n = 107)	43	100

Source: Our elaborations.

FILMTYPE indicates the type of material used for mulching (conventional or biodegradable). It assumes a value equal to 1 if the farmers use conventional films (in polyethylene), 2 if the farmers use biodegradable films (in Mater-bi) and 0 if the farmers don't adopt the mulching technique. The variable indicates the compatibility level with the current technology. The compatibility is the degree to which an innovation is perceived to be consistent with the existing values, past experiences and potential adopters' needs. An idea that is more compatible is less uncertain to the potential adopter and fits more closely with the individual's situation (Rogers, 2005). The underlying assumption is that farmers who have already adopted the mulching technique, and especially those who already use biodegradable materials, are more inclined to take the innovative films with respect to those who do not practice the mulch. In fact, according to the theory of innovation, the adoption process of innovation, represented in this study by biodegradable films derived from organic waste, is facilitated by the level of compatibility with existing technologies (i.e., biodegradable films in Mater-Bi).

3. Results

The number of potential adopters of SBOs films is reported in Table 2. A total of 64 farmers, who represent 60% of the sample (n=107), were willing to adopt the films containing SBOs. The remaining 40% of the sample stated that they would not be willing to adopt SBOs films; among these, 3% already use biodegradable materials, 17% adopt conventional films and the remaining 20% do not adopt any mulching technique.

Findings show that the majority of potential adopters are farmers who already adopt the mulching technique and specifically, farmers who use biodegradable materials.

The rationales for the non-willingness to adopt that were expressed by the farmers during the interviews are summarized in Table 3.

The interviewees declared that they do not employ mulching because of the high purchase cost of materials and installation, mainly labor costs (28%), and the difficulties occurring during the mechanical harvesting (12%).

The other reasons lie in the type of material. Many respondents reported some concerns about the quality of the films, such as the rapid degradation of a biodegradable film (19%), and various doubts about the agronomic consequences of a biodegradable film on the crop (21%). Finally, the rationale expressed by the farmers, related to the non-willingness to use SBOs films, is the onset of doubts about the environmental and agronomic performance, such as moisture, duration, pollutants, and so on (9% of the non-potential adopters of SBOs films).

Table 4 outlines the summary statistic results of WTP prices for adopting SBOs-based films in € ha^{-1}. The highest frequency is concentrated between 450 and 495 €ha^{-1} (32% and 27% of potential adopters), which are the prices of the first bid that equals the current price of common biodegradable films and the 10% increased price.

The results of the WTP regression analysis (in-

Table 4 - *Summary statistics of WTP for the sample (€/ha).*

WTP	**Frequency**	**Percent**	**Cumulated Percent**
200	1	1.6	1.6
250	2	3.2	4.8
300	4	6.5	11.3
360	4	6.5	17.8
405	2	3.2	21.0
450	20	32.3	53.3
495	17	27.4	80.7
540	4	6.5	87.2
550	2	3.2	90.4
600	3	4.8	95.2
700	2	3.2	98.4
750	1	1.6	100.0
TOTAL	62*	100	

Source: Our elaborations.
*The sample includes the respondents who were willing to adopt films from SBOs but did not use a mulching technique; this is why it is different from the sum of conventional, biodegradable and both film users.

Table 5 - *Estimation results of the Heckman selection model (two steps).*

Variables	Coefficient
First stage, probit analysis	**Sample selection**
Sample selection (willingness to adop	
1.EXTJOB	1.321** (0.51)
1.film_type (conventional film)	0.785** (0.36)
2.film_type (biodegradable film)	2.111*** (0.49)
land_quar	0.371** (0.15)
1.rot_cover	-1.817** (0.71)
family_job	-0.307** (0.15)
_cons	-0.979** (0.47)
Second-stage, OLS analysis	**WTP (EUR/ha)**
1.EXTJOB	21.41 [21.41] (31.27)
1.film_type (conventional film)	70.51* [70.51] (40.81)
2.film_type (biodegradable film)	24.21 [24.21] (49.22)
HA_MULCH	11.85 [13.65] (13.65)
AGE_levels	14.58 [14.58] (14.18)
durability_2	40.12* [40.12] (23.28)
strength_2	29.39* [29.39] (16.92)
_cons	229.0*** (75.75)
lambda	67.82* (34.98)
Number of obs	104
Censored obs	43
Uncensored obs	61
Wald chi2(7)	17.09
Prob > chi2	0.02
rho	0.75
sigma	90.73

Robust standard error in round brackets. Marginal effects dy/dx (mean) in square brackets.
*** significant at the 1% .
** significant at the 5%.
* significant at the 10%.
Restrict observations if WTP>=250
Source: Our elaborations.

cluding marginal effects) obtained applying Heckman's two-step selection model (by using the software Stata, ver. 12.0) are reported in Table 5. As for the sample selection model, in order to calculate the inverse Mills Ratio and apply it to the sample selection model, the probit model was run first. The dependent variable was binary, representing whether the farmer was willing to adopt or not (1, 0).

All the variables included in the first step are a significant determinant of the willingness to adopt. According to the expected sign and economic theory (substitution between technology and cheap labor when it is provided by the farmer and his family members), the negative coefficient referring to *FAMLAB* indicates that farms endowed with family labor are less keen to adopt biodegradable films containing SBOs. The results related to *FILMTYPE* (conventional or biodegradable film) indicate that the farmers already using the mulching as a technique have a higher probability of adoption, and, more specifically, those who adopt the biodegradable materials are even keener to adopt, compared to those using the conventional ones. This result confirms the underlying assumption of the compatibility level with the current technology, which is that the biodegradable films containing SBOs represent an incremental innovation, which is perceived as consistent with the farmers' experience and the potential adopters' needs. In this case, farmers who usually adopt the mulch and biodegradable materials seem to have a greater knowledge about the films and, therefore, are keener to also adopt films from SBOs (which differ from marketable mulching films only for the origin of the materials). Therefore, they will be more likely to adopt the innovation compared to farmers who do not use mulch or who use only plastic films. The sign of these values is consistent with the expected sign, indicating the compatibility level with the current technology. The *SIZE* coefficient is positive and significant at 5% and indicates that the larger the irrigated surface, the higher the probability of using the innovative films. The reason is that the mulch allows for water saving; thus, the larger the surface, the greater the benefits of reducing the usage of water. The negative sign obtained for *ROTCOV* is coherent with expectations; in fact, the crop rotation practice allows for controlling certain weeds. Therefore, those who are already rotating crops with coverage are less likely to adopt the mulch. *EXTJOB* has a positive effect on the probability of adopting innovation. The less labor available to the farm is positively associated with the adoption of innovation.

As for the second step of the econometric analysis, the farmers who were not willing to pay for biodegradable films containing SBOs were truncated from the sample, and the regression was conducted by using the Heckman sample selection model, including the inverse mill ratio as one of the independent variables in the regression. We find a significant lambda (λ) in the Heckman model, with a positive estimate of 67.82 EUR ha^{-1}. Thus, the numerical value suggests that there are selection effects in these data and that those who choose to adopt have higher WTP prices than what a random selection from the population of farmers with a comparable set of characteristics would pay. This shows that the average WTP of all horticultural producers in Foggia Province is actually much less than those who would be willing to adopt the mulching technique.

In the second step, the sociodemographic characteristics (*AGE* and *EXTJOB*) were not significant, including the agro-economic factor measuring the hectares of land with mulch (*MULCH*). The estimate results of the second stage regression reveal that the farmers who use the conventional would pay more than biodegradable users and for greater durability and strength of the films. In fact, the coefficient of the variables *FILMTYPE* was included in the model as a dummy, and *DURABILITY* and *STRENGTH* are significant at 10% with positive sign.

To determine the presence of multicollinearity, we calculated the Variance Inflation Factor (VIF). The results of the mean VIF were 1.04 for the determinants included in the first step and 1.43 for the regressors in the second step.

4. Concluding remarks

This study examined the farmers' willingness to adopt biodegradable films containing SBOs and identified the factors influencing the farmers' WTP for this innovation. The WTP was obtained by applying Heckman's two-step model. The first step, estimating the willingness to adopt, showed that the increased availability of adoption comes from farmers who already use the mulch, and especially by those who already adopt biodegradable materials. In addition, according to the economic theory, the size of irrigated land, which indirectly indicates the need for water resources, positively influences the willingness to adopt, as the mulch technique will favor water saving. In addition, the adoption of land management practices, such as rotation with cover crop and the use of family labour, negatively influences the adoption of innovation. From the second step, aimed at estimating the variables affecting the WTP, the results show that the farmers using conventional films are more willing to pay than those already using biodegradable materials. Finally, findings imply that the films' attributes, like durability and strength, are positive determinants for WTP.

Results showed that farmers have demonstrated their willingness to not only adopt the mulching films obtainable from the exploitation of agricultural and urban waste but also to pay a premium price for a greater durability and integrity of the films, thus showing no prejudice toward the origin of the materials. Although the results of this research may not be representative of larger farming areas due to the limited sample size, findings have provided a value for the potential market of biodegradable mulching films from SBOs, thus representing a way to increase environmental sustainability in agriculture. Moreover, the use of biodegradable mulching films (particularly those complying with UNI 11495/2013) is one of the volunteer activities implemented by the farmers financed by the European Union under the Common Agricultural Policy (CAP). For the 2014-2020 period, Measure 10, called "*Payment for agri-environment-climate commitments*", is drawn up as the line of action through which the European Union is preparing to compensate farmers for the increased cost and profit loss that may result from the adoption of more sustainable voluntary production methods. This policy measure has been adopted by the European Union in order to sustain some cultivation practices which reduce the environmental impact, but whose higher cost is not compensated by the market. Therefore, these types of public payment may be considered within the so-called "green box", as stated in Annex 2 of the Agricultural Agreement of the World Trade Organization.

It is worth mentioning that voluntary measures engagement is not only conditioned by factors related to the amount of payment but it also depends on transaction costs related to the socioeconomic and political institutions in which farmers operate. Therefore, a significant barrier to the voluntary adoption of SBOs films (and overall, of eco-innovation) is represented by its own transaction costs, which would confirm that farmers who do not use yet neither mulching nor biodegradable materials could also be less prompt to apply these voluntary measures. The new programming instruments provided by the community legislature and aimed at environmental protection should therefore allow recipients to also support transaction costs.

Appendix A

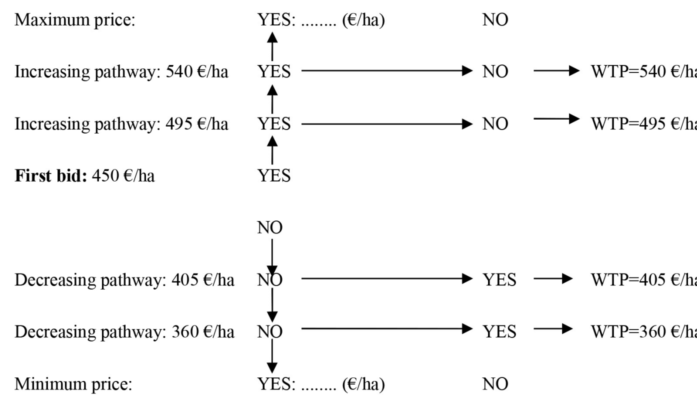

Fig. A1 - *Sequence of CV questions (WTP).*

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