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Adoption of Innovation in Agriculture: A Critical Review of Economic and Psychological Models

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Abstract
Two main models have been used to analyze farmers' decisions to adopt an innovation; the first is based on the concept of utility maximization (UM) and the second is based on the theory of planned behavior (TPB). This study uses a vote-count method to identify the effect of different variables on farmers' adoption decisions in 36 studies using either UM or the TPB. Results from the UM studies show that the explanatory variables mostly have an insignificant effect on the adoption decision. When the effects are significant, the sign of the effect is inconsistent across studies. Results from the TPB studies show that correlations between the psychological constructs used in this type of model are significant in most cases. However, most variables are only used in one or two studies and it is therefore not possible to detect a clear pattern across studies that used the TPB model.
Keywords*:* Adoption; Farmer; Innovation; Utility; Theory of reasoned action; Theory of planned behavior.

Biographical notes

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1 Introduction

Agricultural production methods have to be sustainable in economic, ecological, and social terms, in order to provide food for the growing global population (Ahnstrom et al., 2008). Agricultural innovations impact in the level of food production and the state of the global environment (Tilman et al., 2002). As farmers decide which innovations will be implemented in their farms, it is important to understand farmers' decisions on adoption of innovations. Two main types of models are used to analyze farmers' decisions to adopt an innovation[1]. The first type of model is based on the concept of utility maximization (UM) and the second type is based on the socio-psychological theory of reasoned action (TRA), and its extension, the theory of planned behavior (TPB). As UM and TRA/TPB models are widely applied to understand farmers' adoption decisions, it is critical to review studies that use these two models.

Earlier attempts to synthesize the literature on the adoption of innovation in agriculture include Knowler and Bradshaw (2007) and Prokopy et al. (2008). These studies used a vote- count method to review studies on conservation practices (Knowler and Bradshaw, 2007), and on best management practices (Prokopy et al., 2008). Results showed that the effects of specific variables on the adoption decision are often insignificant and not consistent across studies. These reviews, however, did not focus on the types of models used by researchers. Therefore, a literature review, focusing on UM and the TRA/TPB, is necessary to identify if there are specific variables in these models, which consistently explain farmers' decisions to adopt an innovation. In addition, a review allows for an in-depth understanding of how each model approaches the topic of adoption, highlighting their strong and weak points.

The objectives of this study were twofold. First, to identify the variables that have been included in studies that use either UM or the TRA/TPB and the effect of these variables on the adoption decision. Second, to use the results of this review to highlight and contrast the strengths and weaknesses of the UM and TRA/TPB models. The results are expected to provide researchers with insight into how well the UM and TRA/TPB models can be applied to understand farmers' decisions to adopt an innovation. Furthermore, the results of this study also highlight potential improvements for future research on farmers' decisions to adopt an innovation in agriculture. The identification of specific variables that influence farmers' decisions to adopt an innovation could also provide insights to policy makers that can be used to adjust current policies and design new policies and programs to stimulate the adoption of sustainable innovations.

2 Methodology

A quantitative approach was used to review 36 studies (26 UM and 10 TRA/TPB) that were identified through a comprehensive search of the Scopus database. The search was conducted using a specific list of keywords[2]. We restricted the search to peer-reviewed studies, published from 2000 to 2014. The quantitative analysis aimed to identify which variables have been included in studies that use either UM or the TRA/TPB, and the effect of these variables on the adoption decision.

The studies based on UM that were selected are summarized in Table A1 in the Appendix. A study was included in the review if it explicitly used UM[3], and if at least one of the models used in the study investigated the adoption of one or more innovations as a dependent variable (or provided sufficient information to allow us to identify the variables that influenced the adoption decision).

TRA/TPB studies were chosen according to more general criteria, because UM is used much more frequently than TRA/TPB in adoption of innovation studies. Studies were included in the review if they used the TRA/TPB to explain farmers' decisions and behaviors, and presented at least one model correlating two or more psychological constructs based on TRA or TPB. Models that measured TRA or TPB constructs but did not

[1] In this study, innovation encompasses all kinds of technologies. We use the definition given by Rogers (2003): "An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Using such a broad concept, there are many studies that can be classified as part of the literature on adoption in agriculture. For instance, the adoption of innovation literature includes studies focused on conservation practices, environmentally friendly innovations, agricultural best-management practices, water conservation practices, etc.

[2] Keywords used in the search were: adoption of innovation, adoption decision, technology adoption, conservation technology adoption, best management practices adoption, sustainable practices adoption, adoption of environmentally friendly practices, adoption of integrated pest management practices, behavior, theory of reasoned action, and theory of planned behavior. All these words were used with the word farmer or farmers.

[3] There were many others studies that empirically analyzed the impact of the UM concept, mainly profitability and risk attitudes, on the adoption decision. However, we focused on studies that explicitly used this concept to explain adoption.

correlate them with other constructs were not included in the review. The TRA and TPB studies selected for the quantitative analysis are presented in the Appendix in Table A2.

Following the selection of studies for review, we constructed two databases. One was for variables used in UM studies, and the other was for variables used in TRA/TPB studies. We used a vote-count methodology, which entailed the construction of tables of significance counts from the reviewed studies (Prokopy et al., 2008). A variable was assumed to have a significant effect if the parameter was significant at the critical 10% level. In our review, some variables appeared to be used very frequently, but were actually only used in a few studies. This is because some studies included a number of different models and tested for the same independent variables across all the models.

Three procedures provided some structure for the large number of independent variables in the UM database. First, given similarities between the variables used in different studies, an aggregation was undertaken.[4] Second, a variable was only included in the final UM table (Table 1) if it was used in at least three different studies.[5] Finally, we classified variables into groups. To check the robustness of the results, we further disaggregated the analysis for two groups of innovations, i.e. environmental and system innovations. Thirty-one and twenty-nine independent variables were used to study the adoption of environmental and system innovations, respectively.

In the final TRA/TPB table (Table 2), we only show the variables that represented the psychological constructs from these theories.

3 Results and discussion

3.1 UM studies

The main assumption in the UM type of model is that farmers make adoption decisions based on utility considerations, and that their actions are consistent with the objective of maximizing their utility (Adesina and Zinnah, 1993; Batz et al., 1999). The central argument is that a farmer adopts an innovation if the utility from adopting exceeds the utility from not adopting, or if the utility from adopting a technology exceeds the utility from adopting another available technology.

Table 1 shows the synthesis of the most frequently used variables in the studies based on UM, which we reviewed. Variables were grouped into five categories: farmer characteristics, farm characteristics, household characteristics, farming context, and acquisition of information/learning process (column 1 in Table 1). The specific variables and the number of times each appeared in the models that we analyzed are presented in columns 2 and 3 of Table 1. For each variable, we calculated the frequency of significant positive effects, significant negative effects, and insignificant effects (columns 4, 5, and 6 in Table 1) on the decision to adopt an innovation. The last column in Table 1 shows the number of studies in which a specific variable was used. This shows that although some variables were only used in a few studies, they were often used in multiple models in the same study. For instance, *risk aversion* was only used in 4 of the 26 studies, but appeared in 35 models.

Using the three procedures explained in Section 2, we decreased the number of independent variables from 120 to 31. The initial number of variables was high, and consistent with Prokopy et al.'s (2008) observation that many independent variables in studies on the adoption of innovation are included without any theoretical basis. In addition, independent variables that are more easily measured appeared in most of the reviewed studies. For instance, *age, education level, farm size, assets,* and *assistance or contact with extension* were used in at least half of the 26 studies. Prokopy et al. (2008) also highlighted this result. They argued that variables that are more easily measured are included in many studies, and often authors do not even discuss a theoretical reason for the inclusion of these variables – they appear to be included simply because it is expected.

The frequency analysis in Table 1 shows that an insignificant effect on the adoption decision was more frequent than a significant effect for the majority of the variables. This finding is consistent with results from the reviews of Knowler and Bradshaw (2007) and Prokopy et al. (2008). In the results presented in Table 1, 23 of the 31 variables had an insignificant effect more frequently than a significant effect. Two of the variables had a significant effect in half of the models (*soil type or fertility or characteristics* and *income from agriculture*). Only six variables had a significant effect more frequently than an insignificant effect, i.e. *irrigation, slope category, farm size, distance to the farm from home, attendance at training sessions or on-farm demonstrations,* and *membership in farmers' associations or other groups*.

[4] We grouped variables that were similar but not necessarily identical. For example, some authors measured education as a dummy variable and others as years of schooling. For our purposes, we combined variables such as this together into the single measure, *educational level*. Prokopy et al. (2008) also used this approach for grouping variables related to the adoption decision.

[5] Knowler and Bradshaw (2007) also used this cut-off point, because variables that are used infrequently are unlikely to provide much information or to show a pattern across empirical studies.

When the variable had a significant effect on the adoption decision, the sign was often not consistent across studies, with the variable positively affecting the adoption decision in some models and negatively in others. This was the case for 19 of the 31 variables. This result is also in line with the findings of Knowler and Bradshaw (2007) and Prokopy et al. (2008). In our review, the 11 variables that showed a consistent sign were used in only a few of the reviewed studies. Only *access to credit* and *membership in farmers' associations or other groups* were used in more than five studies. The other nine variables were used in five or fewer studies. Knowler and Bradshaw (2007) argued that one could expect that, as the number of studies that used a specific variable increased, the results would show convergence toward a particular finding (significant and same sign, or insignificant). Similar to our results, this expectation was not confirmed in their study. They found that the greater the number of studies, which used a specific variable, the less consistent was the causal effect of the variable.

When we consider the results by groups of variables, the variables classified as farmer and household characteristics had an insignificant effect more frequently than a significant effect, except for *income from agriculture* (significant in half of the models). The farmer characteristics *gender, education level*, and *age,* and the household characteristic *assets* were used in a large number of studies. When the effect was significant, two farmer characteristics had a consistent sign: *risk-aversion* and *experience in farming*. No household characteristics showed a consistent sign. In the farm characteristics group, three variables (*irrigation*, *slope category*, and *farm size*) had a significant effect more frequently than an insignificant effect, and hired *labor* and *irrigation* also had a consistent sign. In this group, *farm size* was the only variable that was used in more than half of the studies. In the farming context group, only *distance to the farm from home* had a significant effect more frequently than an insignificant effect. Three farming context variables showed a consistent sign across studies, i.e. *credit, security of land tenure,* and *distance to the farm from home*. *Region* was the variable used most often in the farming context group, although it was used in less than half of the studies. In the information/learning group, two variables frequently had a significant effect, *Attendance at training sessions or on-farm demonstrations* and *membership in farmers' associations or other groups*. These two variables and *farmer perceptions of the problem that the innovation can help to solve* also had a consistent sign. In this group, *assistance or contact with extension* was the most frequently used variable.

Table 1 – Frequency of significant and insignificant effects on the adoption decision for the independent variables in the UM studies; results from the vote-count methodology

Group	Variable	No. of models	Sig (+)	Sig (-)	Insig	No. of studies
Farmer characteristics	Off-farm work	7	14.3%	14.3%	71.4%	4
	Risk-aversion	35	0.0%	22.9%	77.1%	4
	Gender (male)	33	30.3%	6.1%	63.6%	11
	Educational level	71	40.8%	7.1%	52.1%	21
	Experience in farming	9	22.2%	0.0%	77.8%	5
	Age	68	10.3%	10.3%	79.4%	20
Farm characteristics	Diversification	39	46.1%	2.6%	51.3%	5
	Have a lake or stream	39	23.1%	10.2%	66.7%	4
	Hired Labor	8	25.0%	0.0%	75.0%	5
	Irrigation	7	85.7%	0.0%	14.3%	5
	Soil type or fertility or characteristics	12	33.3%	16.7%	50.0%	7
	Slope category (flatter higher probability to adopt)	10	60.0%	10.0%	30.0%	5
	Farm size	39	64.1%	5.1%	30.8%	20
	Land tenure (owner)	42	16.7%	4.8%	78.5%	7
Household characteristics	Income from agriculture	36	47.2%	2.8%	50.0%	4
	Family labor	18	0.0%	0.0%	100.0%	3

	Income	37	29.7%	2.7%	67.6%	7
	Assets (agricultural or non-agricultural)	62	16.1%	3.2%	80.7%	15
	Family size	15	20.0%	26.7%	53.3%	8
	Off farm income	19	5.3%	21.0%	73.7%	6
Farming context	Participate in government environmental programs or receive subsidies	17	41.2%	0.0%	58.8%	3
	Region	30	36.7%	10.0%	53.3%	11
	Distance from village or farm to town or market or input shop	13	23.1%	15.4%	61.5%	7
	Credit	15	46.7%	0.0%	53.3%	8
	Security of land tenure	6	16.7%	0.0%	83.3%	3
	Distance to the farm from home	9	0.0%	66.7%	33.3%	5
	Extent of erosion in the village or in the farm	89	23.6%	6.7%	69.7%	5
Information/learning	Attendance at training sessions or on-farm demonstrations	8	87.5%	0.0%	12.5%	3
	Farmer perception about problem that the innovation can help to solve	6	16.7%	0.0%	83.3%	3
	Membership in farmers' associations or other groups	12	66.7%	0.0%	33.3%	7
	Assistance or contact with extension	90	38.9%	6.7%	54.4%	18

Our findings can be summarized as follows. The effects of independent variables are frequently insignificant. When the effects are significant, the sign is often contradictory. Hereafter, we will discuss possible explanations for these results.

Four reasons could explain the frequently insignificant effect for most of the variables presented in Table 1. First, there are no independent variables that provide a generic explanation of farmers' decisions to adopt an innovation (see also Knowler and Bradshaw, 2007). Second, there are different ways to measure a specific independent variable, and the way these variables are measured influences the effect on the dependent variable. Although this is not a valid explanation for variables that are easily measured, it could explain the results for more complex variables, such as *risk-aversion*. Third, multi-collinearity between independent variables influences the effect of a specific variable. For example, a model that includes *age* and *experience* tends to result in an insignificant effect for both variables, although these variables could individually and jointly affect the adoption decision. Finally, the independent variables usually influence the adoption decision in more than one way. For instance, *age* may increase *experience* and hence have a positive impact on the adoption decision. However, *age* also decreases the time horizon and older farmers may also be more *risk-averse*, in which case, *age* would have a negative impact on the decision. If the positive and negative effects cancel each other out, then a model that includes *age* as an independent variable would reveal an insignificant effect. This last argument may also explain the contradictory signs in cases where variables have a significant effect. For instance, farmers with a higher *educational level* may have greater ability and knowledge to adopt a complex innovation. This variable would then have a positive impact on the adoption decision. On the other hand, farmers with a higher *education level* may more easily find a job outside the farm, which would mean that they would not adopt an innovation. In that case, *education level* would have a negative sign.

The inconsistent effects of the independent variables on the adoption decision, which we found in our review, may have been caused by aggregating variables from studies that dealt with different types of innovations with different objectives. As explained in section 2, we further disaggregated the analysis for two groups of innovations, environmental and system innovations. The results of the disaggregated analysis are presented in Table A3 in the Appendix.

On the disaggregated analysis, an insignificant effect was more frequent than a significant effect for 21 variables in the studies on the adoption of environmental innovations, and for 17 variables in the studies on the adoption of system innovations. These results are consistent with the results from the aggregated analysis, suggesting that our general finding that most independent variables had an insignificant effect on the adoption decision was not due to aggregation. However, a more consistent pattern was evident for the signs of the significant parameters. Whereas in the aggregated analysis (Table 1) only 11 significant parameters had a consistent sign, when environmental and system innovations were considered separately this number increased to 17 and 13, respectively. In this supplementary investigation, we were particularly interested in variables that showed a consistent sign according to the type of innovation. Our results show that the variable *lake or stream* frequently had an insignificant effect on the adoption of both types of innovations. However, when the effect was significant, the sign of the coefficient was consistent for the type of innovation, i.e. a positive effect for environmental and negative impact for system innovations. This pattern also occurred for the variable *land tenure*.

3.2 TRA/TPB studies

The TRA and TPB attempt to frame human behavior in a limited number of psychological constructs (Beedell and Rehman, 2000). Both theories assume that human behavior originates from the individuals' intentions to perform a specific behavior (Hansson et al., 2012). By introducing behavioral intention, these models are restricted to those behaviors that are under the volitional control of the individual, that is, that are performed because the person consciously wishes to perform them (Burton, 2004).

In the TRA, intention (*I*) is determined by two central constructs, attitude (*ATT*) and subjective norm (*SN*). The TPB is an extension of the TRA, and assumes that perceived behavioral control (*PBC*) also influences intention (Ajzen, 1991). Attitude, subjective norm, and perceived behavioral control originate from, respectively, behavioral beliefs, normative beliefs, and control beliefs (Ajzen, 1991). The general TPB model is presented in Figure 1.

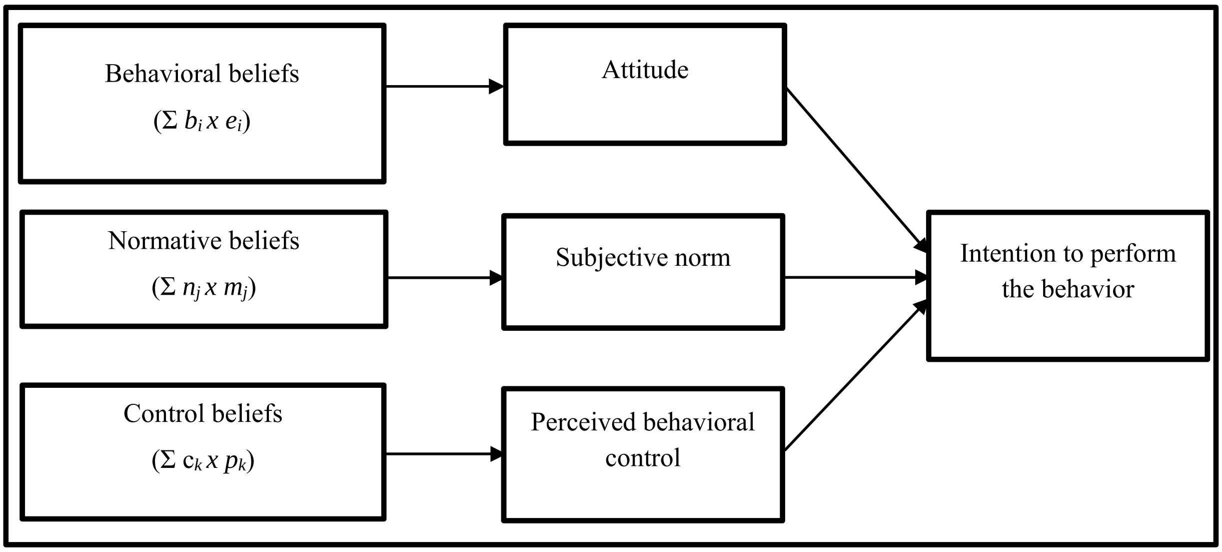

Figure 1. The TPB model (adapted from Ajzen, 2005).

According to Beedell and Rehman (2000) and Wauters et al. (2010), *I* is the intention to perform the behavior, *ATT* is the degree to which execution of the behavior is positively or negatively evaluated, *SN* refers to people's perceptions of the social pressures upon them to perform or not perform a behavior, and *PBC* is the perceived own capability to successfully perform a behavior.

In the TPB, attitude is derived from behavioral beliefs ($b_i \times e_i$), where b_i is the belief about the likelihood of outcome i^{th} of the behavior, and e_i is the evaluation of the i^{th} outcome (Wauters et al., 2010). The subjective norm is derived from normative beliefs ($n_j \times m_j$), where n_j is the belief about the normative expectations of the j^{th} important referent, and m_j is the motivation to comply with the opinion of the j^{th} important referent (Wauters et al., 2010). Perceived behavioral control originates from control beliefs ($c_k \times p_k$), where c_k is the belief about the presence of the k^{th} factor that may facilitate or inhibit the performance of the behavior, and p_k is the perceived power of the k^{th} factor to facilitate or inhibit the behavior (Wauters et al., 2010). The sums of behavioral beliefs, normative beliefs, and control beliefs result in indirect measures of attitude, subjective norm, and perceived behavioral control, respectively.

All of the studies based on TRA/TPB, which we reviewed, used beliefs and/or the psychological constructs of intention, attitude, subjective norm and perceived behavioral control. Although the variables used in the models differed little across studies, the emphasis given to each of the psychological constructs and how they are measured did differ across studies, as noted by Burton (2004).

We faced two challenges in reviewing the TRA/TPB studies. First, psychological constructs are used interchangeably as dependent and independent variables in different models. This is understandable, as the TRA/TPB predicts that there are correlations between more than two psychological constructs. If a model allowed us to classify whether a psychological construct was used as a dependent or independent variable, we followed the classification of the authors. Otherwise, we based this classification on the TRA/TPB structure presented in Figure 1.

The second challenge was more problematic. Different studies measured psychological constructs in different ways. In order to define the psychological construct to which a specific measurement belonged, we based the analysis on the intentions as stated by the authors. The results in Table 2 should be interpreted in the following manner. Variables that were used in the studies as dependent variables are shown in column 1; for each dependent variable, column 2 shows the independent variables that were used in the models. For instance, when behavior was a dependent variable, the independent variables used in at least one model were intention, attitude, subjective norm, perceived behavioral control, behavioral beliefs, normative beliefs, and control beliefs. Column 3 shows the number of models that found a significant correlation between each dependent and independent variable; column 4 shows the number of models for which the correlation was insignificant. For example, when behavior was the dependent variable, this psychological construct had a significant correlation with attitude in three of the models analyzed. The last column in Table 2 shows the number of studies that used each combination of dependent and independent variables.

Table 2 – Frequency of significant and insignificant correlations between dependent and independent variables in the TRA/TPB studies; results from the vote-count methodology

Dependent variable	Independent variable	Sig	Ins	No. of studies
Behavior	Intention	3	0	1
	Attitude	3	0	2
	Subjective norm	2	0	1
	Perceived behavioral control	3	5	2
	Behavioral beliefs	5	3	1
	Normative beliefs	0	8	1
	Control beliefs	3	5	1
Intention	Attitude	12	1	5
	Subjective norm	11	1	6
	Perceived behavioral control	5	4	2
	Behavioral beliefs	40	26	3
	Normative beliefs	17	25	3
	Control beliefs	3	6	1
Attitude	Behavioral beliefs	12	8	1
Subjective norm	Normative beliefs	9	1	1
Perceived behavioral control	Control beliefs	2	10	1

In general, correlations between the psychological constructs were more frequently significant than insignificant. Ten of the sixteen possible correlations were mostly significant and only one correlation was insignificant in all cases, which was behavior with normative beliefs. The correlation between control beliefs and the other psychological constructs was also generally insignificant. The TPB predicts that perceived behavioral control originates from control beliefs, however our results show that this correlation was significant in only two of the twelve models.

Following the structure of the TRA/TPB presented in Figure 1, we found that farmers' intentions to perform a specific behavior are mostly correlated with their attitudes and subjective norm, and less often with perceived behavioral control. Our review also suggests that farmers' attitudes and subjective norm are correlated with their behavioral beliefs and normative beliefs, respectively.

The other finding from the vote-count is that studies based on the TRA/TPB did not follow a common approach. Most of the correlations were used in just one or two studies. Burton (2004) argued that many studies that use a behavioral approach make little mention of subjective norm as a contributor to intention. In our review, the correlation between intention and subjective norm was the only one that was used in more than five studies.

4 Discussion of strengths and weaknesses of UM and TRA/TPB approaches

UM and TRA/TPB models have similar theoretical backgrounds, i.e. both approaches are part of the larger expectancy-value framework (Feather, 1982; Lynne, 1995). The subjective expected utility model, which is mainly used in the economic literature, and the TRA/TPB, which is mainly used in the social-psychology literature, are extensions of the expectancy value (Lynne, 1995). Indeed, the attitude concept in the TRA/TPB is closely related to the utility notion, in that attitude reflects and measures latent utility (Lynne, 1995). In effect, UM and TRA/TPB are the same model in a theoretical sense, differing in an operational sense. Despite the similarities in the two types of approaches, UM and TRA/TPB use very different sets of variables to explain the adoption decision. Whereas TRA/TPB models use psychological constructs, the most frequently used explanatory variables in UM models are farming context, information/learning, farmer characteristics, farm characteristics, and household characteristics.

Our review showed that studies based on the TRA/TPB analyze decisions and behaviors in a deeper way than studies based on UM. Researchers who used TRA/TPB models usually started with a pre-survey of key stakeholders in order to identify the potential outcomes for a specific behavior, potentially important referents, and possible factors that facilitate or prevent the behavior. This first step gives researchers that use the TRA/TPB an advantage, because it allows them to develop survey questions that capture what farmers think is important, rather than what researchers think is important.

Another strength of the TRA/TPB is that it explicitly considers the role of social pressure upon farmers to adopt an innovation, by using the subjective norm construct. Similarly, researchers use perceived behavioral control to identify barriers that could restrict farmers' adoption behavior. This psychological construct can play an important role in agriculture, given that farmers are subject to fluctuations in the physical, economic, and political environments (Burton, 2004).

An inherent weakness of TRA/TPB models is that researchers do not usually measure the revealed behavior, but rather the intention to perform a specific behavior. Another weakness of TRA/TPB studies is that a strict application of the questionnaire is time-consuming, leaving little time for exploring other influences (Burton, 2004). The questionnaire usually focuses on a very specific innovation and the results are therefore not generalizable to a wider context. A further weakness of this approach is the lack of consistency in the methodology among studies on adoption in agriculture. This complicates the comparison of results from studies that use this framework. In addition, studies that use the TRA/TPB do not explicitly consider the role of other potential explanatory factors, such as farmer, farm, and household characteristics, farming context, and acquisition of information/learning process.

A strength of the UM model is that, in practice, it captures the 'real' behavior of farmers, using the concept of revealed preference. That is, a farmer's decision to adopt an innovation is based on utility maximization and it is assumed that his/her preference is revealed by observing his/her behavior. Another strength of the UM approach is that the variables that are most frequently used in this type of model are more easily measured than psychological constructs. Researchers who use UM can compare their results with a wider range of studies. This is not only because UM is widely used, but also because these types of studies follow a similar approach and methodology.

Both UM and TRA/TBP models ignore the latest findings in behavioral economics and neuroeconomics (see e.g. Kahneman (2011) and Wilkinson and Klaes (2012) for an overview). These disciplines can explain how the brain actually works and can point to causes rather than correlations. Although the topic exceeds the scope of this study, some authors have suggested a way to integrate ideas from UM and TRA/TPB models in a different and creative way (Bishop et al., 2010; Chouinard et al., 2008; Lynne, 19955; Lynne and Casey, 1998; Lynne et al., 19955; Sautter et al., 20111). These studies also recognize the latest findings in behavioral economics and neuroeconomics, indicating a potentially productive direction for future research on farmers' decisions and behaviors.

5. Concluding comments and implications

The studies reviewed in this paper, based on either UM or the TRA/TPB, used many correlations, but failed to find underlying causes for adoption behavior. There are many correlated factors but few, if any, causal factors Results showed that the UM studies used a large number of variables, some of which lacked a theoretical basis. Only a few variables included in the UM studies are clearly linked to utility maximization, such as risk attitude and profitability of the innovation. Most of the variables included in the UM studies had an insignificant effect more frequently than a significant effect. If there was a significant effect, the sign of the coefficient was not consistent across studies. These results are in line with the findings from other reviews. We presented three reasons that could explain this lack of convergence, in addition to the argument of Knowler and Bradshaw (2007) that there are no independent variables that can consistently explain adoption.

There are some suggested improvements for future studies that use UM model to understand farmers' decisions to adopt an innovation. First, a key insight that is missing from the UM model is that there is an interaction aspect that influences the effect of some variables. For example, adoption depends on the risk associated with an innovation, and the degree of risk-aversion of the decision maker. Or, on how profitable the innovation is and how strongly the potential adopter is motivated by profit. Abadi Ghadim and Pannel (1999) provide a framework for utility maximization that considers this interaction aspect. Second, variables must be included in UM models only if there is theoretical support.

Results from the TRA/TPB studies showed that correlations between the psychological constructs were more often significant than insignificant. However, the review showed that most variables used on TRA/TPB model were only used in one or two studies, so it was not possible to detect a clear pattern across studies that used the TRA/TPB model. In addition, studies on adoption in agriculture that use the TRA/TPB model suffer from a lack of consistency in the measurement of the psychological constructs. That is, researchers did not measure the psychological constructs as preconized by these theories. Therefore, a suggested improvement for future research that use TRA/TPB models to understand farmers' adoption decisions is to develop the questionnaire to collect data following the guidelines suggested by Fishbein and Ajzen (2010). The review also showed that most studies do not measure the adoption behavior, but rather the intention to adopt an innovation. This is particularly a problem because it is known that intention will not always result in behavior. To solve this problem we suggest that researchers collect TRA/TPB data in two points in time. The ideal approach would be to apply a questionnaire to measure intention to adopt and the other psychological constructs, and later on another questionnaire with the same farmers to analyze whether farmers who showed intention to use the innovation do really use it on their farms.

From a policy maker perspective, our results are in line with the recommendations of Knowler and Bradshaw (2007). These authors argue that as there are no clear universally significant factors affecting adoption, developing policies to promote globally the adoption of sustainable innovations is particularly challenging. Therefore, Knowler and Bradshaw (2007) proposed that policies should consider the specificities of the target population and of the region where the innovation will be promoted.

A potential limitation of this study concerns the vote-count method. One of the limitations of this method is that it does not take into account the sample size of the populations used in the different studies. For instance, as sample size increases, the probability of obtaining a statistically significant result increases. Another limitation is that we restricted the search of papers from 2000 until 2014 and only to peer reviewed papers available in the Scopus database. Although we acknowledge that this choice may bias the results, we believe that expanding the search to a longer period and to additional databases would not substantially change the results. Knowler and Bradshaw (2007) and Prokopy et al. (2008) found similar results with bigger samples. Finally, the number of peer reviewed studies that use TRA/TPB was relatively small. This might be the case because of the keywords used in the search. While we acknowledge that a larger number of studies is preferred, we argue that our results are sufficiently well documented to provide a "picture" of how these models have been applied in studies on adoption of innovation in agriculture.

Appendix

Tables A1, A2 and A3.

Table A1 - Studies based on UM, which were included in the review

Authors	Model ( )*	Country	Innovation
Adesina and Chianu (2002)	Logit (1)	Nigeria	Alley farming technology
Anley et al. (2007)	Tobit (4)	Ethiopia	Soil conservation practices
Asfaw and Admassie (2004)	Logit (2)	Ethiopia	Chemical fertilizer
Bekele and Drake (2003)	Multinomial logit (1)	Ethiopia	Soil and water conservation practices
Cavatassi et al. (2011)	Probit (1)	Ethiopia	Modern sorghum varieties
D'Emden et al. (2008)	Logit (1)	Australia	No-till
Feleke and Zegeye (2006)	Logit (1)	Ethiopia	Maize varieties
Gedikoglu and McCann (2012)	Probit (4)	United States	Environment-oriented, profit-oriented and win-win practices
Gillespie et al. (2007)	Multinomial logit (16)	United States	Best management practices
Jara-Rojas et al. (2012)	Poisson regression model (1), Logit (2) and Mutinomial logit (1)	Chile	Water conservation practices
Kim et al. (2005)	Probit (16)	United States	Best management practices (16)
Lambert et al. (2007)	Probit (1) and Multinomial logit (1)	United States	Conservation practices
Lapar and Ehui (2004)	Probit (1)	Philippines	Dual-purpose forage
Larson et al. (2008)	Logit (1)	United States	Remote sensing for variable-rate application of inputs
Mariano et al. (2012)	Logit (1) and Poisson regression model (1)	Philippines	Certified rice seed and Integrated package of rice production technologies
Mazvimavi and Twomlow (2009)	Tobit (1)	Zimbabwe	Conservation practices
Moser and Barret (2006)	Probit (1) and Tobit (1)	Madagascar	System of rice intensification
Noltze et al. (2012)	Double-hurdle (2)	Timor Leste	System of rice intensification
Sidibé (2005)	Probit (2)	Burkina Faso	Soil conservation ('zai' technique) and water conservation ('stone trip') practices
Somda et al. (2002)	Logit (3)	Burkina Faso	Composting technology (soil fertility)
Teklewold and Kohlin (2011)	Multinomial logit (1)	Ethiopia	Soil conservation practices (stone terraces and soil bunds)
Wubeneh and Sanders (2006)	Tobit (2)	Ethiopia	Sorghum varieties (Striga resistant) and inorganic fertilizer
Xu and Wang (2012)	Heckman probit (2)	China	Artisan fruit production
Zhang et al. (2012)	Logit (1)	China	Raising sheep in folds
Zheng et al. (2012)	Probit (1)	China	Plant varieties
Zhou et al. (2008)	Logit (1)	China	Water-saving technology (called ground cover rice production system)

* Number of analyzed models

Table A2 - Studies based on the TRA/TPB, which were included in the review

Authors	Theory	Model	Country	Behavior/Innovation
Beedell and Rehman (2000)	TPB	Correlation	United Kingdom	Conservation behavior
Bruijnis et al. (2013)	TPB	Correlation	Netherlands	Improve dairy cow foot health
Hansson et al. (2012)	TPB	Multinomial logit	Sweden	Decision to diversify or specialize
Läpple and Kelley (2013)	TPB	Probit	Ireland	Organic agriculture
Martínez-Garcia et al. (2013)	TRA	Correlation	Mexico	Improved grassland management
Mettepenningen et al. (2013)	TPB	Logit	Belgium and United States	Agri-environmental schemes
Pennings and Leuthold (2000)	Not mentioned	Covariance structure model	Netherlands	Futures contract usage
Poppenborg and Koellner (2012)	TPB	Multinomial logit	South Korea	Agricultural land use practices
Rehman et al. (2007)	TRA	Correlation	England	Recommended observation times for heat detection
Wauters et al. (2010)	TPB	Logit	Belgium	Soil conservation practices

Table A3 – Frequency of significant and insignificant effects on the adoption decision, for variables included in UM studies on the adoption of environmental and system innovations; results from the vote-count methodology

Group	Variable	Environmental innovations				System innovations			
		No. of models	sig (+)	sig (-)	insig	No. of models	sig (+)	sig (-)	insig
Farmer characteristics	Off-farm work	6	16.8%	16.8%	66.7%	1	0.0%	0.0%	100.0%
	Risk-aversion	21	0.0%	14.3%	85.7%	14	0.0%	35.7%	64.3%
	Gender (male)	20	45.0%	10.0%	45.0%	13	7.7%	0.0%	92.3%
	Educational level	43	41.9%	2.3%	55.8%	28	39.3%	14.3%	46.4%
	Experience in farming	6	16.7%	0.0%	83.3%	3	33.3%	0.0%	66.7%
	Age	40	10.0%	10.0%	80.0%	28	10.7%	10.7%	78.6%
Farm characteristics	Diversification	24	54.2%	4.2%	41.6%	15	33.3%	0.0%	66.7%
	Have a lake or stream	26	34.6%	0.0%	65.4%	13	0.0%	30.8%	69.2%
	Hired Labor	7	14.3%	0.0%	85.7%	1	100.0%	0.0%	0.0%
	Irrigation**	1	100.0%	0.0%	0.0%	6	83.3%	0.00%	16.7%
	Soil type or fertility or characteristics	4	50.0%	0.0%	50.0%	8	25.0%	25.0%	50.0%
	Slope category (flatter higher probability to adopt)	7	71.4%	14.3%	14.3%	3	33.3%	0.0%	66.7%
	Farm size	20	75.0%	5.0%	20.0%	19	52.6%	5.3%	42.1%
	Land tenure (owner)	26	26.9%	0.0%	73.1%	16	0.0%	12.5%	87.5%
Household characteristics	Income from agriculture	23	65.2%	0.0%	34.8%	13	15.4%	7.7%	76.9%
	Family labor	11	0.0%	0.0%	100.0%	7	0.0%	0.0%	100.0%
	Income	22	31.8%	0.0%	68.2%	15	26.7%	6.7%	66.7%
	Assets (agricultural or non-agricultural)	39	20.5%	2.6%	76.9%	23	8.7%	4.4%	86.9%
	Family size	10	20.0%	10.0%	70.0%	5	20.0%	60.0%	20.0%
	Off farm income	11	0.0%	9.1%	90.9%	8	12.5%	37.5%	50.0%
Farming context	Participate in government environmental programs or receive subsidies	16	43.7%	0.0%	56.3%	1	0.0%	0.0%	100.0%
	Region	16	25.0%	6.2%	68.8%	14	50.0%	14.3%	35.7%

	Distance from village or farm to town or market or input shop	4	25.0%	0.0%	75.0%	9	22.2%	22.2%	55.6%
	Credit	6	16.7%	0.0%	83.3%	9	66.7%	0.0%	33.3%
	Security of land tenure	6	16.7%	0.0%	83.3%	0	0.0%	0.0%	0.0%
	Distance to the farm from home	6	0.0%	83.3%	16.7%	3	0.0%	33.3%	66.7%
	Extent of erosion in the village or in the farm	58	32.8%	1.7%	65.5%	31	6.4%	16.1%	77.4%
Information/ Learning	Attendance at training sessions or on-farm demonstrations	2	100.0%	0.0%	0.0%	6	83.3%	0.0%	16.7%
	Farmer perception about problem that the innovation can help to solve	6	16.7%	0.0%	83.3%	0	0.0%	0.0%	0.0%
	Membership in farmers associations or other groups	8	75.0%	0.0%	25.0%	4	50.0%	0.0%	50.0%
	Assistance or contact with extension	54	24.1%	3.7%	72.2%	36	61.1%	11.1%	27.8%

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