Awareness and Attitudes towards Biotechnology Innovations among Farmers and Rural Population in the European Union

LUIZA TOMA[1], LÍVIA MARIA COSTA MADUREIRA[2], CLARE HALL[1], ANDREW BARNES[1], ALAN RENWICK[1]

[1] Scottish Agricultural College, UK
[2] University of Tras-os-Montes e Alto Douro, Portugal
Contact e-mail: luiza.toma@sac.ac.uk

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Abstract: The paper analyses the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations and access to/trust in information on these issues (amongst other *a priori* determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. We employ structural equation models (SEM) with observed and latent variables. SEM is a statistical technique for testing and estimating relationships amongst variables, using a combination of statistical data and qualitative causal assumptions. We use an Eurobarometer dataset (2010) about awareness/acceptance of biotechnology innovations and run SEM models for ten EU countries, which include older and newer Member States. The variables included are socio-demographics, access to biotechnology information, trust in information sources on biotechnology innovations, attitudes towards the importance and impact of science and technology on society, perceptions of the risks and benefits of the applications of biotechnology innovations and attitudes towards their implementation in practice. Results between the different EU countries are comparable and, alongside other determinants, trust in information sources will significantly impact perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. This underlines the importance of information and knowledge to acceptance of biotechnology innovations, which should be a key point on policy-makers' agenda of developing the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Increasing awareness of biotechnology innovations that safeguard people and the environment in order to enable informed debate and decisions will help enhance sustainability of rural areas.

Key words: biotechnology innovations, farmers and rural population, European Union, information and knowledge, biotechnology attitudes, structural equation models.

1 Introduction

Feeding a growing population against limited resources and mitigating climate change imply an increasing need for innovation, which requires a coordinated effort from decision makers, industry and the public. Capitalising on innovations offered through agricultural biotechnology will contribute to increase the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Hence, awareness of biotechnology innovations amongst both industry (*e.g*., farmers) and the public (*e.g*., rural population as a whole) is a key factor influencing their attitudes and potentially leading to positive behavioural change.

There is an increasing literature analysing people's biotechnology attitudes (Allum *et al*., 2008; Bauer, 2005; Bruhn, 2003; Durant *et al*., 2000; European Commission, 2008; European Commission, 2010; Frewer *et al*., 1996; Phipps and Park, 2002; Teisl *et al*., 2002). They state that knowledge and information are significant factors influencing attitudes and perceptions of biotechnology.

The paper analyses the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations (biofuels, resistance to disease in apples, genetically modified food, animal cloning) and trust in information on these issues (amongst other *a priori* determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice.

2 Data and Methods

2.1 Data

The data used in this study were extracted from the Dataset Eurobarometer 73.1: Life Sciences and Biotechnology. The Eurobarometer survey was carried out by TNS Opinion & Social through face-to-face interviews of citizens in the 27 Member States of the European Union plus Croatia, Iceland, Norway, Switzerland and Turkey (Eurobarometer, 2010).

The original database includes data on socio-demographics (education, gender, age, occupation, number of children living in the household, religion, political affiliation, perceived level in society); access to biotechnology information; trust in information sources on biotechnology innovations; attitudes towards the importance and impact of science and technology on society; perceptions about biotechnology regulation; perceived responsibility to ensure that biotechnologies benefit everyone; interest about scientific discoveries and technological developments; perceptions about public involvement in decision-making about science and technology; perceptions of the risks and benefits of the applications of biotechnology innovations; and attitudes towards their implementation in practice. The questionnaire included explanatory statements about biotechnologies.

We selected datasets for ten countries (Great Britain, Austria, Belgium, Finland, France, Netherlands, Poland, Portugal, Slovakia and Slovenia). The countries have a good geographical coverage (Western, Northern, Southern and Central-Eastern Europe) and include old and new European Union (EU) member countries. A main reason for the choice of countries was to analyse populations at the opposite ends as regards their attitudes towards the implementation in practice of biotechnology innovations. Namely, as regards their attitudes towards biotechnology developments to increase resistance to disease in apples, Poland and Finland support the concept, while Slovenia does not. As regards their attitudes towards biofuels, Slovakia and Netherlands support the concept, while Austria does not. As regards their attitudes towards cloning, Slovakia and Slovenia support the concept, while Belgium and France do not. As regards their attitudes towards genetically modified foods, Great Britain and Portugal support the concept, while France does not. The datasets have between 110 and 261 observations. The variables included in the analysis are socio-demographic (gender, age, number of children (0-14 years old) living in the household, education, occupation – farmer, religion), trust in information sources on biotechnology issues, self-assessed level of biotechnology information, perceptions about risks and benefits of the applications of biotechnology innovations, and attitudes towards the implementation in practice of biotechnology innovations.

2.2 Method

We use structural equation models (SEM) with observed and latent variables to test the influence of *a priori* identified determinants on attitudes towards biotechnology innovations. SEM is a statistical technique used to test and estimate causal relationships amongst variables, some of which may be latent, based on a combination of statistical data and qualitative causal assumptions. Latent variables are not directly observed but inferred from other variables that are directly measurable (Bollen, 1989). The concept of causality may be controversial (Mueller, 1996), however, SEM is not intended to ascertain causes but to assess the accuracy of the causal relationships *a priori* identified in the literature. Hence, SEM is mostly used as a confirmatory analysis/theory testing tool.

SEM may consist of two components, namely the measurement model (which states the relationships between the latent variables and their constituent indicators), and the structural model (which designates the causal relationships between the latent variables). The measurement model resembles factor analysis, where latent variables represent ‘shared’ variance, or the degree to which indicators ‘move’ together. The structural model is similar to a system of simultaneous regressions, with the difference that in SEM some variables can be dependent in some equations and independent in others.

The model is defined by the following system of equations in matrix terms (Jöreskog and Sörbom, 2007):

The structural equation model: $$\eta = B\eta + \Gamma\xi + \zeta \quad (1)$$

The measurement model for y: $$y = \Lambda_y \eta + \varepsilon \quad (2)$$

The measurement model for x: $$x = \Lambda_x \xi + \delta \quad (3)$$

Where: η is an mx1 random vector of endogenous latent variables; ξ is an nx1 random vector of exogenous latent variables; B is an mxm matrix of coefficients of the η variables in the structural model; Γ is an mxn matrix of coefficients of the ξ variables in the structural model; ζ is an mx1 vector of equation errors (random disturbances) in the structural model; y is a px1 vector of endogenous variables; x is a qx1 vector of predictors or exogenous variables; Λ_y is a pxm matrix of coefficients of the regression of y on η; Λ_x is a qxn matrix of coefficients of the regression of x on ξ ; ε is a px1 vector of measurement errors in y; δ is a qx1 vector of measurement errors in x.

The paper estimates SEM with the normal-theory maximum likelihood (MLE) method using the statistical package Lisrel 8.80 (Jöreskog and Sörbom, 2007).

Latent variables and indicators

Table 1 presents a description of the latent variables and their corresponding indicators. There are nineteen latent variables with their corresponding 48 indicators forming sixteen models, namely: three models estimating the impact of determinants on attitudes towards genetically modified foods (Great Britain, France, Portugal); six models estimating the impact of determinants on attitudes towards artificially introducing either a resistance gene from another species or a gene that exists naturally in wild/crab apples into an apple tree to make it resistant to mildew/scab (Poland, Slovenia, Finland); three models estimating the impact of determinants on attitudes towards biofuels (Austria, Slovakia, Netherlands); and four models estimating the impact of determinants on attitudes towards cloning (Belgium, France, Slovenia, Slovakia).

Table 2 presents a series of descriptive statistics for the indicators of the latent variables included in the models.

Table 1. Description of latent variables and their corresponding indicators

Latent variable	Indicator	Statement	Variable type
genders	gender	gender	dichotomous
ages	age	age	categorical
childs	child	number of children (0-14 years old) living in the household	categorical
educs	educ	education	categorical
farmers	farmer	occupation - farmer	dichotomous
relig	relig1	God beliefs	categorical
info	info1	How informed do you feel about new medical discoveries	ordinal-three-point Likert scale
	info2	How informed do you feel about new scientific discoveries and technological developments	ordinal-three-point Likert scale
infojob	infojob1	Trust in newspapers, magazines and television which report on biotechnology	dichotomous
	infojob2	Trust in industries which develop new products with biotechnology	dichotomous
	infojob3	Trust in university scientists who conduct research in biotechnology	dichotomous
	infojob4	Trust in consumer organisations which test biotechnological products	dichotomous
	infojob5	Trust in environmental groups who campaign about biotechnology	dichotomous
	infojob6	Trust in national government making laws about biotechnology	dichotomous
	infojob7	Trust in retailers who ensure our food is safe	dichotomous
	infojob8	Trust in the European Union making laws about biotechnology for all EU Member States	dichotomous
	infojob9	Trust in ethics committees who consider the moral and ethical aspects of biotechnology	dichotomous
	infoj10	Trust in medical doctors	dichotomous
gmaware	gmohear	Have you ever heard of genetically modified (or GM) foods before?	dichotomous
gmoatd	gmoatd1	GM food is good for your country's economy	ordinal-four-point Likert scale
	gmoatd2	GM food helps people in developing countries	ordinal-four-point Likert scale
	gmoatd3	GM food is safe for future generations	ordinal-four-point Likert scale
	gmoatd4	GM food is safe for your health and your family’s health	ordinal-four-point Likert scale
	gmoatd5	GM food does no harm to the environment	ordinal-four-point Likert scale
gmo	gm	The development of GM food should be encouraged	ordinal-four-point Likert scale
appatdo		Artificially introducing a resistance gene from another species into an apple tree to make it	

		resistant to mildew/scab:	
	appatdo1	is a promising idea	ordinal-four-point Likert scale
	appatdo2	would still mean that eating apples will be safe	ordinal-four-point Likert scale
	appatdo3	will harm the environment	ordinal-four-point Likert scale
	appatdo4	is fundamentally unnatural	ordinal-four-point Likert scale
	appatdo5	makes you feel uneasy	ordinal-four-point Likert scale
appleo	appatdo6	should be encouraged	ordinal-four-point Likert scale
		Artificially introducing a gene that exists naturally in wild/crab apples which provides resistance to mildew/scab:	
	appatds1	will be useful	ordinal-four-point Likert scale
appatds	appatds2	will be risky	ordinal-four-point Likert scale
	appatds3	will harm the environment	ordinal-four-point Likert scale
	appatds4	is fundamentally unnatural	ordinal-four-point Likert scale
	appatds5	makes you feel uneasy	ordinal-four-point Likert scale
apples	appatds6	should be encouraged	ordinal-four-point Likert scale
	statd1	Even if it brings no immediate benefits, research adding to knowledge should be supported by Government	ordinal-five-point Likert scale
statd	statd2	New inventions will always be found to counteract any harmful effect of scientific/ technological developments	ordinal-five-point Likert scale
	statd3	The benefits of science are greater than any harmful effects it may have	ordinal-five-point Likert scale
biofuels	biofuel	To what extent do you think biofuels should be or not be encouraged?	ordinal-four-point Likert scale
	sbiofuel	To what extent do you think sustainable biofuels should be or not be encouraged?	ordinal-four-point Likert scale
	clonat1	Animal cloning in food production is good for your country's economy	ordinal-four-point Likert scale
	clonat2	Animal cloning in food production helps people in developing countries	ordinal-four-point Likert scale
clonat	clonat3	Animal cloning in food production is safe for future generations	ordinal-four-point Likert scale
	clonat4	Animal cloning in food production is safe for your health and your family’s health	ordinal-four-point Likert scale
	clonat5	Animal cloning in food production does no harm to the environment	ordinal-four-point Likert scale
cloning	clon	Animal cloning in food production should be encouraged	ordinal-four-point Likert scale

* Some of the variables described above were measured on a four-point Likert scale (as originally designed in the Eurobarometer questionnaire), which excluded the middle alternative of ‘neither agree nor disagree’. The literature is divided as regards the impact the number of scale points used for Likert-type items have on the reliability of responses. After reviewing a number of studies with contradictory results, Alwin and Krosnick (1991) found that five-point scales are not more reliable than four-point scales and that middle alternatives may lower reliability of measurement (they may become more valuable in longer response forms, e.g., seven-point scales). In addition, the original options of response in the Eurobarometer questionnaire included the ‘don’t know’ option, which would account to some extent for the ambiguous opinions, usually captured by the neutral ‘neither agree

nor disagree’. While, again, not straightforward, this might increase reliability/reduce reliability errors by filtering out respondents with wide latitudes of acceptance/rejection (Alwin and Krosnick, 1991). In our analysis we treated the ‘don’t know’ responses as missing data and discarded those observations.

Table 2. Descriptive statistics (mean and standard deviation) for the variables

	GMO						Apple						Biofuels								Cloning					
	GB		FR		PT		PL		SI		FI		AT		SK		NL		BE		FR		SI		SK	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
gender			1.59	.493	1.56	.498	1.55	.499	1.53	.500	1.52	.502	1.50	.501	1.58	.495	1.51	.501	1.53	.500	1.59	.493	1.53	.500	1.58	.495
age			4.04	1.593	3.47	1.779	3.69	1.670	3.92	1.597			3.70	1.499	3.34	1.519	3.75	1.634	3.96	1.651	3.89	1.684	3.92	1.597	3.37	1.664
child			.62	.898	.39	.772	.60	1.021	.33	.711			.41	.792	.69	.997			.40	.840	.53	.930	.33	.711	.68	.981
educ			3.43	1.098	2.62	1.010	3.21	.975	3.36	1.049			2.96	.922	3.17	.688			3.69	1.104	3.52	1.135	3.36	1.049	3.17	.690
farmer	.05	.209	.11	.316	.05	.222	.11	.310	.08	.274	.11	.318	.12	.324	.06	.243	.15	.359	.10	.307	.14	.352	.08	.274	.09	.280
relig1	1.81	.773	2.09	.830	1.29	.574	1.14	.413	1.89	.778	1.68	.698	1.56	.674	1.30	.591			1.90	.792	2.18	.837	1.89	.778	1.38	.667
info1	2.10	.649	1.95	.572	2.60	.574							2.39	.576	2.40	.598										
info2	2.20	.688	2.04	.607	2.64	.532	2.49	.633	2.27	.611	2.37	.598	2.45	.622	2.53	.560			2.35	.628	2.06	.632	2.27	.611	2.47	.629
infojob1			1.42	.496	1.16	.365	1.13	.341					1.16	.366	1.10	.298					1.48	.501				
infojob2															1.09	.291	1.13	.337	1.16	.366						
infojob3			1.06	.238	1.08	.276	1.08	.271	1.17	.376					1.06	.231	1.03	.180	1.06	.241	1.06	.234	1.17	.376	1.13	.341
infojob4	1.12	.325	1.10	.296											1.06	.242			1.05	.223	1.07	.263	1.31	.465	1.19	.391
infojob5	1.31	.465			1.09	.284			1.27	.443	1.35	.479									1.20	.399	1.27	.443		
infojob6	1.47	.503																	1.19	.392						
infojob7			1.29	.454															1.17	.379						
infojob8	1.52	.503							1.30	.459															1.14	.343
infojob9																							1.23	.424		
infoj10					1.08	.268	1.12	.329	1.12	.323											1.10	.296	1.12	.323		
gmohear			1.12	.328	1.46	.500																				
gmoatd1	2.44	.698	2.95	.859																						
gmoatd2			2.66	.944	2.54	.866																				
gmoatd3	2.56	.785	3.30	.771	2.90	.779																				
gmoatd4	2.55	.884	3.20	.885	3.02	.865																				

gmoatd5			3.16	.926																						
gm	2.70	.893	3.23	.877	2.94	.819																				
appatdo1							2.54	.976	2.98	.971	2.73	.989														
appatdo2							2.83	.955	3.22	.803	3.00	.900														
appatdo3							2.18	.915	1.95	.895	2.08	.870														
appatdo4							1.76	.692	1.54	.754	1.75	.797														
appatdo5							1.96	.814	1.70	.815	2.21	.974														
appatdo6							2.85	.986	3.28	.813	3.02	.949														
appatds1							1.97	.887	2.43	1.017	2.02	.934														
appatds2							2.47	.932	2.38	.982	2.58	.936														
appatds3							2.59	.959	2.44	1.027	2.67	.887														
appatds4							2.34	.950	2.00	.980	2.60	.878														
appatds5							2.47	.934	2.25	1.016	2.75	.984														
appatds6							2.21	.991	2.60	1.022	2.16	1.039														
statd1													2.68	1.099	2.05	.915										
statd2													2.49	.850	2.52	.887										
statd3													2.70	.879	2.59	.902										
biofuel													1.94	.873	1.62	.642	2.00	.910								
sbiofuel													1.74	.765	1.54	.622	1.43	.629								
clonat1																			3.17	.720	3.22	.847	3.47	.717	2.93	.805
clonat2																			2.84	.884	3.08	.913	3.00	.946	2.69	.837
clonat3																			3.12	.768	3.45	.703	3.33	.829	2.97	.809
clonat4																			3.15	.787	3.41	.794	3.43	.789	3.06	.834
clonat5																			2.91	.856	3.16	.911	3.02	1.007	2.83	.819
clon																			3.39	.709	3.56	.665	3.45	.766	3.08	.775
Sample Size	110		197		231		196		233		133		261		224		192		220		242		233		222	

3 Results and Discussion

We tested the models and the path diagrams for the estimated models are conceptually presented in Figure 1 to Figure 4 [1].

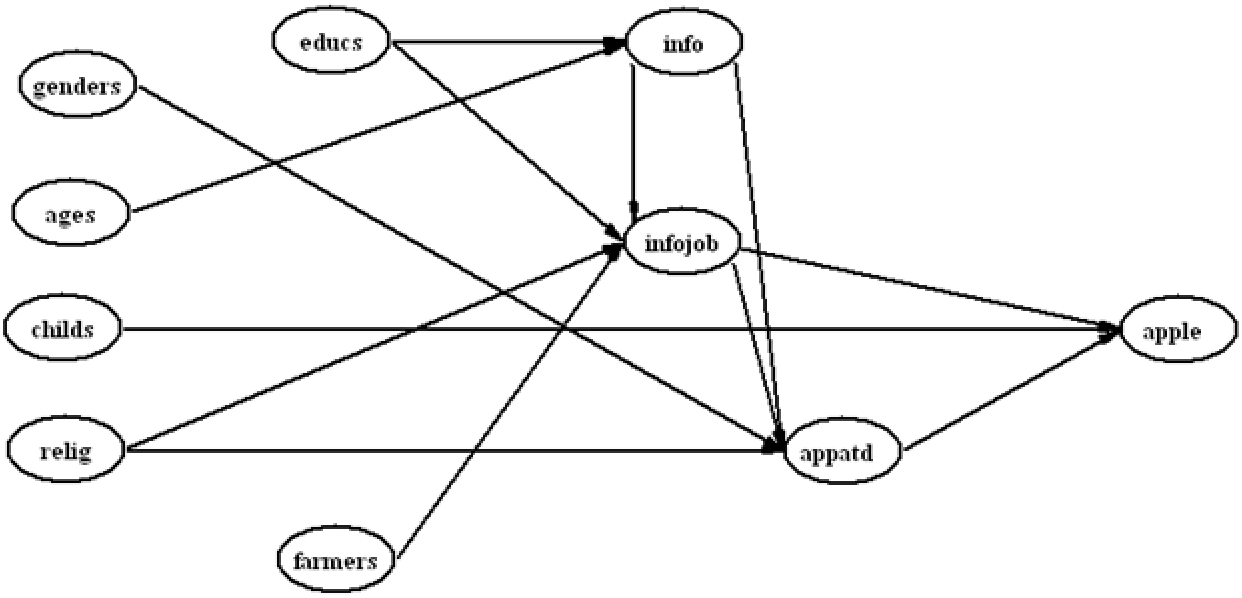

Figure 1. Conceptual diagram for ‘apple’ models

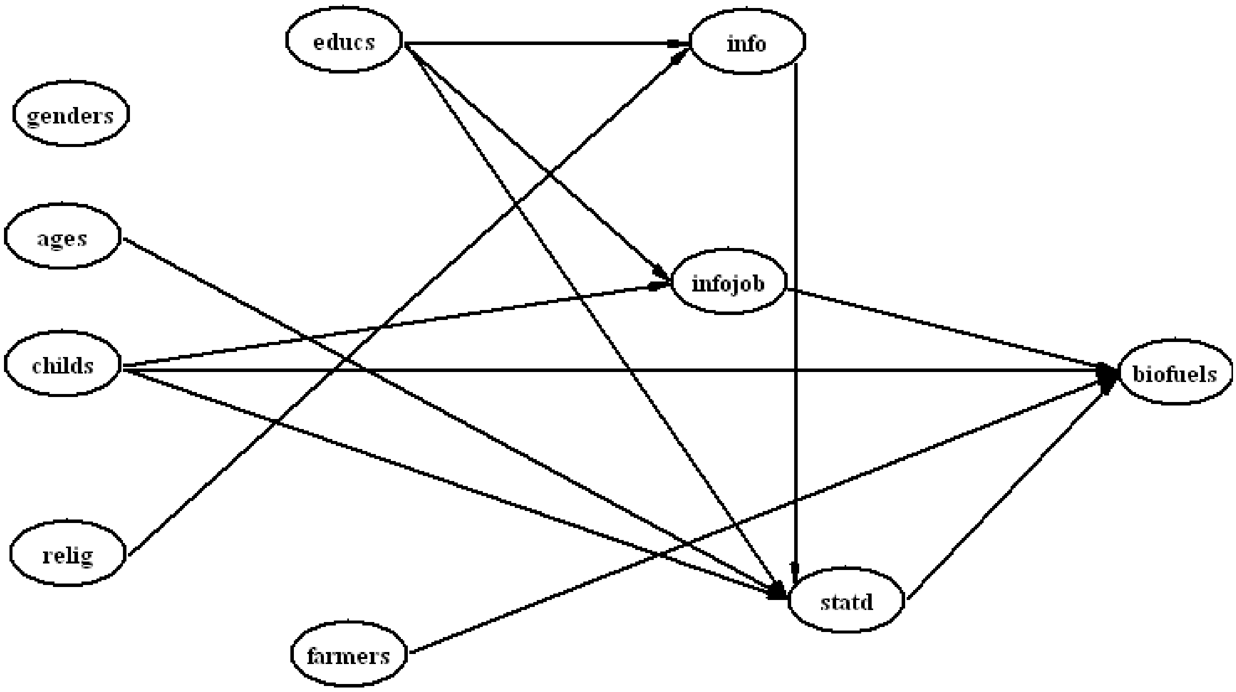

Figure 2. Conceptual diagram for ‘biofuels’ models

[1] Path diagrams for each of the 16 models (standardised solution) are available on request.

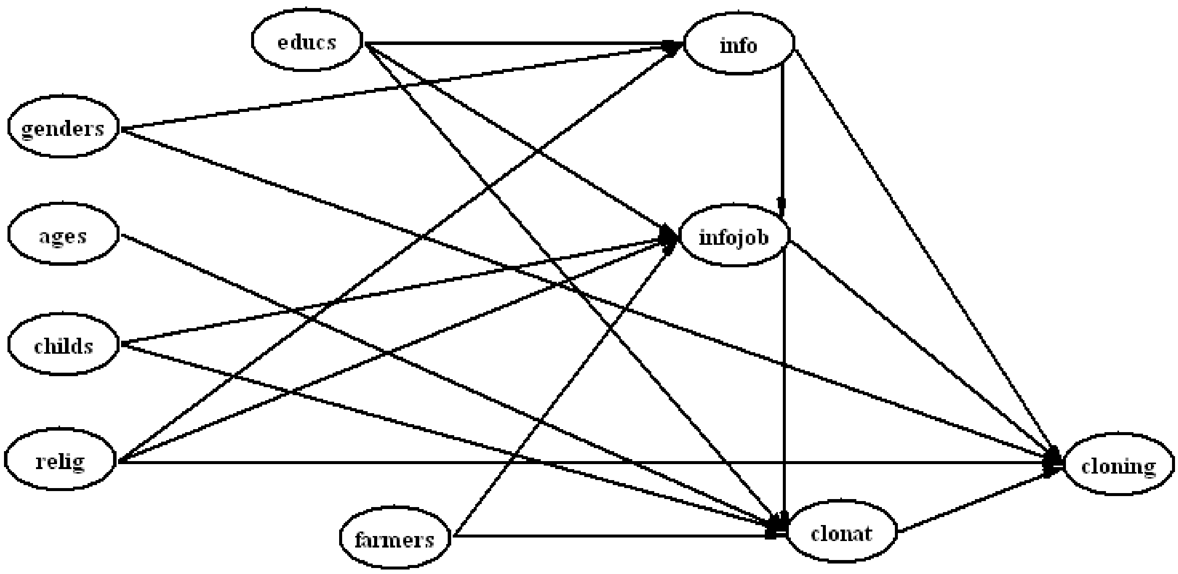

Figure 3. Conceptual diagram for 'cloning' models

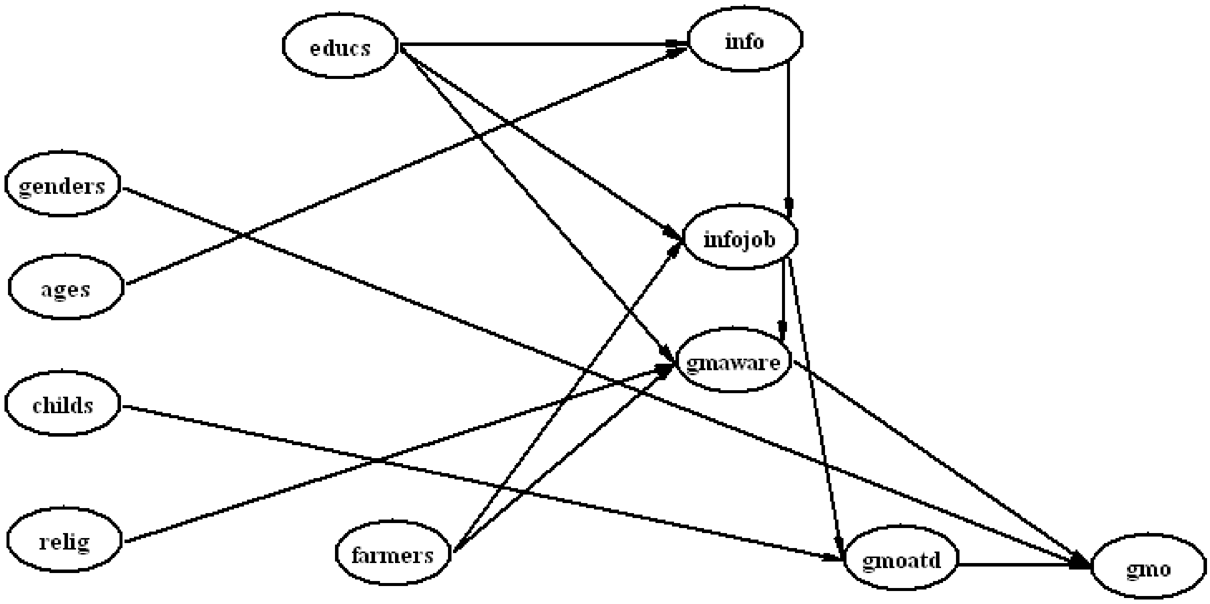

Figure 4. Conceptual diagram for 'GM' models

All models have a good fit according to the measures of absolute, incremental and parsimonious fit (Hair et al., 2006). The main goodness of fit (GoF) indicators (estimated and recommended values) for the estimated models are presented in Table 3.

Table 3. Goodness of fit indicators

GoF indicators	GMO			Apple-other species			Apple-same species			Biofuels			Cloning				Recommended value
	GB	FR	PT	PL	SI	FI	PL	SI	FI	AT	SK	NL	BE	FR	SI	SK	
Degrees of Freedom	52	132	100	90	111	29	85	105	32	59	98	12	126	124	124	81	
Normal Theory Weighted Least Squares Chi-Square	96.97	166.16	188.46	123.79	146.85	64.94	129.31	110.22	68.10	143.91	130.76	12.04	204.34	160.47	152.87	249.29	Low
Normed chi-square	1.86	1.26	1.88	1.38	1.32	2.24	1.52	1.05	2.13	2.44	1.33	1.00	1.62	1.29	1.23	3.08	[1-3]
Root Mean Square Error of Approx. (RMSEA)	0.089	0.036	0.062	0.044	0.037	0.097	0.052	0.01	0.092	0.074	0.039	0.0043	0.053	0.035	0.032	0.097	<0.10
Non-Normed Fit Index (NNFI)	0.76	0.89	0.81	0.88	0.86	0.92	0.74	1.00	0.94	0.81	0.87	1.00	0.80	0.85	0.90	0.83	>0.90
Comparative Fit Index (CFI)	0.81	0.91	0.86	0.91	0.89	0.96	0.82	1.00	0.96	0.88	0.90	1.00	0.83	0.88	0.92	0.89	>0.90
Incremental Fit Index (IFI)	0.82	0.92	0.86	0.91	0.89	0.96	0.83	1.00	0.96	0.88	0.91	1.00	0.84	0.88	0.93	0.89	>0.90
Standardised Root Mean Square Residual (SRMR)	0.097	0.058	0.074	0.065	0.064	0.058	0.057	0.046	0.075	0.057	0.056	0.043	0.069	0.056	0.056	0.060	<0.08
Goodness of Fit Index (GFI)	0.87	0.92	0.91	0.93	0.93	0.92	0.92	0.96	0.91	0.93	0.94	0.98	0.91	0.93	0.93	0.88	>0.90
Adjusted Goodness of Fit Index (AGFI)	0.81	0.88	0.87	0.89	0.90	0.81	0.88	0.94	0.82	0.87	0.90	0.96	0.87	0.91	0.91	0.79	>0.90

Additional testing of the appropriateness of the models was achieved by comparing each of the estimated models with other models that acted as alternative explanations to the proposed models, in a competing models strategy (we used a nested model approach, in which the number of constructs and indicators remained constant, but the number of estimated relationships changed). The results across all types of goodness-of-fit measures favoured the estimated models in most cases. Therefore, we confirmed the accuracy of the proposed models and discarded the competing ones.

An acceptable level of overall goodness-of-fit does not guarantee that all constructs meet the requirements for the measurement and structural models. The validity of the SEM was assessed in a two-step procedure, the measurement model and the structural model.

In the measurement model we tested the reliability of the single-indicator latent variables, namely we tested the 'theory-testing extremes' of reliability within the range of 0.7 to 1 (Ping, 2008) and determined that none of the structural coefficients became non-significant at these extremes. The reliability of the single-indicator latent variables was assumed the value of 0.99.

After assessing the overall model and aspects of the measurement model, the standardised structural coefficients for both practical and theoretical implications were examined. Table 4 presents the standardised total effects on the variables representing the perceived risks and benefits of the applications of biotechnology innovations, and attitudes towards the implementation in practice of biotechnology innovations, of all the other latent variables included in each of the sixteen models.

Table 4. Standardised total (direct and indirect) effects on behavioural latent variable (t-values in parentheses)

Observed/ latent variables	GMO			Apple-other species			Apple-same species			Biofuels			Cloning			
	GB	FR	PT	PL	SI	FI	PL	SI	FI	AT	SK	NL	BE	FR	SI	SK
Total effects on perceived risks and benefits of the applications of biotechnology innovations																
	Total effects on 'gmoatd'			Total effects on 'appatdo'			Total effects on 'appatds'			Total effects on 'statd'			Total effects on 'clonat'			
genders			0.09 (3.28)	-0.02 (-1.74)	0.02 (1.76)	0.29 (2.50)	0.12 (2.09)	0.11 (2.17)	0.27 (2.65)	0.22 (3.17)				0.01 (1.42)	0.06 (1.07)	0.04 (2.55)
ages		0.00 (0.07)	0.03 (2.12)				0.00 (-0.87)			0.27 (3.40)			0.00 (0.94)	0.01 (1.24)		0.21 (4.77)
childs		0.08 (2.12)	-0.02 (-0.61)							0.31 (4.18)						0.13 (3.26)
educs		-0.11 (-3.03)		-0.01 (-1.65)	0.00 (-1.34)		-0.03 (-0.94)	-0.06 (-1.83)		-0.05 (-0.61)			-0.01 (-1.33)	-0.01 (-1.31)	0.00 (-1.07)	0.22 (1.27)
farmers	-0.11 (-2.65)	0.06 (2.76)	-0.02 (-2.02)	0.03 (1.83)		-0.39 (-3.48)	0.04 (2.13)		-0.36 (-3.50)				0.17 (2.89)	0.01 (0.18)	0.18 (3.05)	-0.13 (-2.11)
relig			-0.13 (-3.98)	-0.05 (-2.07)	-0.11 (-2.23)		0.14 (2.74)	-0.07 (-1.34)	-0.06 (-1.94)	-0.07 (-2.08)			0.00 (-1.06)	-0.07 (-1.61)		-0.05 (-1.66)
info	-0.14 (-2.61)	0.16 (2.39)		0.03 (1.84)	0.04 (1.84)	0.13 (1.32)	-0.15 (-1.70)	-0.15 (-1.65)		0.53 (5.97)			0.06 (1.64)	0.06 (1.73)	0.03 (1.18)	0.28 (4.83)
infojob	0.39 (3.31)	0.31 (2.24)		0.18 (2.01)	0.19 (2.51)		0.38 (3.20)	0.30 (2.99)	-0.35 (-5.21)				0.45 (3.25)	0.29 (2.55)	0.14 (2.40)	0.60 (8.09)
gmaware			0.17 (3.07)													
Total effects on attitudes towards the implementation in practice of biotechnology innovations																
	Total effects on 'gmo'			Total effects on 'appleo'			Total effects on 'apples'			Total effects on 'biofuels'			Total effects on 'cloning'			
genders		0.17 (2.34)	0.02 (0.95)	-0.02 (-1.75)	0.02 (1.76)	0.25 (2.45)	0.08 (2.10)	0.09 (2.17)	0.23 (2.75)	0.05 (2.15)	0.18 (3.05)	0.05 (2.09)		0.01 (1.44)	0.04 (1.06)	0.13 (4.33)

ages		0.00	0.00				0.00			0.06		-0.02	0.00	0.01		0.14
		(0.07)	(0.90)				(-0.73)			(2.21)		(-0.35)	(0.95)	(1.26)		(4.84)
childs		0.08	-0.01				0.04			-0.18						0.06
		(2.11)	(-0.61)				(1.90)			(-2.58)						(2.03)
educs		-0.18	0.04	-0.01	0.00		-0.06	-0.05		0.08	-0.02		-0.01	-0.01	-0.01	0.28
		(-3.44)	(3.11)	(-1.66)	(-1.34)		(-1.67)	(-1.83)		(2.47)	(-1.50)		(-1.34)	(-1.33)	(-1.43)	(2.04)
farmers	-0.10	-0.01	-0.01	0.03	0.07	-0.19	0.05		-0.27	0.19	0.04	-0.07	0.19	0.01	0.25	0.00
	(-2.64)	(-0.26)	(-2.01)	(1.83)	(1.42)	(-2.03)	(2.24)		(-3.30)	(2.92)	(0.61)	(-2.20)	(2.97)	(0.18)	(5.04)	(-0.09)
relig		-0.03	-0.02	-0.05	-0.08	0.10	0.05	-0.06	-0.05	-0.02			0.00	-0.10		-0.03
		(-1.89)	(-0.97)	(-2.08)	(-2.23)	(1.97)	(1.08)	(-1.34)	(-1.93)	(-1.69)			(-1.06)	(-1.65)		(-0.94)
info	-0.13	0.17	0.09	0.03	0.03	0.09	-0.07	-0.12	0.09	0.12	0.12		0.07	0.08	0.05	0.21
	(-2.60)	(2.49)	(2.49)	(1.85)	(1.84)	(1.32)	(-1.04)	(-1.65)	(1.67)	(2.62)	(1.67)		(1.65)	(1.78)	(1.72)	(3.25)
infojob	0.35	0.35	-0.37	0.18	0.14	-0.42	0.45	0.25	-0.29	0.37	0.71	0.20	0.50	0.42	0.26	0.63
	(3.29)	(2.32)	(-5.34)	(2.02)	(2.51)	(-10.35)	(3.62)	(2.99)	(-4.96)	(5.37)	(3.03)	(1.99)	(3.36)	(2.72)	(2.77)	(12.85)
gmaware		0.15	0.11													
		(2.01)	(3.10)													
gmoatd	0.89	0.95	0.64													
	(4.57)	(5.97)	(5.73)													
appatdo				0.97	0.71	0.73										
				(5.81)	(6.16)	(11.76)										
appatds							0.69	0.83	0.83							
							(5.05)	(6.71)	(10.42)							
statd										0.22	0.20					
										(2.78)	(2.40)					
clonat													0.82	0.96	0.62	0.68
													(5.64)	(5.06)	(5.79)	(13.16)

Table 4 shows that the only variables which are significant in all models are variables ‘infojob’ and ‘gmaware’.

The variance explained in the ‘gmo’ models varies from 37% in France, 40% in Great Britain to 51% in Portugal. The variance explained in the ‘apple-same species’ models varies from 32% in Poland, 36% in Slovenia to 65% in Finland. The variance explained in the ‘apple-other species’ models varies from 35% in Slovenia, 36% in Poland to 65% in Finland. The variance explained in the ‘biofuels’ models varies from 14% in Netherlands, 25% in Austria to 30% in Slovakia. The variance explained in the ‘cloning’ models varies from 35% in Belgium, 42% in France, 43% in Slovenia to 54% in Slovakia.

In terms of individual effects, perceptions about risks and benefits of the applications of biotechnology innovations (biofuels, resistance to disease in apples, genetically modified food, animal cloning) have the strongest impact on attitudes towards the implementation in practice of biotechnology innovations, with values from 64% to 95% in the gmo models, 69% to 97% in the apples models, 20% to 22% in the biofuels models, and 62% to 96% in the cloning models.

Trust in information sources on biotechnology issues has the strongest impact on perceptions about risks and benefits of the applications of biotechnology innovations, and second strongest impact on attitudes towards the implementation in practice of biotechnology innovations, with values from 14% to 60% and, respectively, from 14% to 71%.

Self-assessed level of information on biotechnology issues shows mixed impacts; while significantly influencing both perceptions about risks and benefits and attitudes towards the development of genetically modified foods (values from 9% to 17%), it is not significant in the apples models, and is significant only in some of the biofuels (Austria) and cloning (Slovakia) models.

Similarly, education significantly influences both perceptions about risks and benefits and attitudes towards the development of genetically modified foods (values from 4% to 18%), it is not significant in the apples models, and is significant only in some of the biofuels (Austria) and cloning (Slovakia) models.

Gender has a lower but significant impact on attitudes towards the implementation in practice of biotechnology innovations in a small majority of models. As regards the other socio-demographic factors, children living in the household and age have a lower impact and significant only in a few models.

Religious beliefs do not significantly influence perceptions about risks and benefits of the applications of biotechnology innovations and attitudes towards the implementation in practice of biotechnology innovations, with the exception of apples-other species models, where it takes values from 5% to 10%.

Compared to the rest of the rural population, farmers have significantly different perceptions about risks and benefits of the applications of biotechnology innovations and attitudes towards the implementation in practice of biotechnology innovations in a number of models, namely: gmo models in Great Britain and Portugal; apples models in Poland and Finland; biofuels models in Austria and Netherlands; cloning models in belgium and Slovenia.

Overall, the ranking of determinants’ impact on attitudes towards the implementation in practice of biotechnology innovations is similar in the majority of models, with perceptions about risks and benefits of the applications of biotechnology innovations as strongest determinant, followed by trust in information sources on biotechnology issues with strong influence, then by self-assessed level of biotechnology information, education and gender with lower impact and ending with religion, children and age, with the lowest influence. This supports findings from the literature that knowledge and information will always impact biotechnology attitudes and perceptions (Allum *et al*., 2008; Bauer, 2005; Bruhn, 2003; Durant *et al*., 2000; European Commission, 2008; European Commission, 2010; Frewer *et al*., 1996; Phipps and Park, 2002; Teisl *et al*., 2002).

4 Conclusion

The paper analysed the impact that European Union (EU) farmers' and rural population's awareness of biotechnology innovations and access to/trust in information on these issues (amongst other a priori determinants) have on their perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. Results between the different EU countries are comparable and, alongside other determinants, trust in information sources will significantly impact perceptions of risks and benefits of the applications of biotechnology innovations, and attitudes towards their implementation in practice. This underlines the importance of information and knowledge to acceptance of biotechnology innovations, which should be a key point on policy-makers' agenda of developing the economic and environmental efficiency in the agricultural sector and rural sustainability in Europe. Increasing awareness of biotechnology innovations that safeguard people and the environment in order to enable informed debate and decisions will help enhance sustainability of rural areas.

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