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On the impact of trust on consumer willingness to purchase GM food: Evidence from a European survey

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Summary *– Many researchers try to explain consumer's acceptance and opposition to genetically modified organisms (GMOs) using social factors like "trust" in "direct causal" or "joint causal" (also referred to as "associationist") models. The latter approach considers attitudes to Genetically Modified foods (GM foods) to be jointly determined by trust and risk perception. With data from a European Survey (Eurobarometer 64.3, 2005), we use a recursive mixed process model to specify the importance of trust in the various organizations involved in the public debate on the acceptance of genetically modified foods on behalf of the "ordinary citizens". We discuss the resulting portrait of European citizens that shows them to be increasingly optimistic about biotechnology, while being divided on this question. We show that corroboration of direct causal or joint causal models depend on the organizations concerned.*

Keywords: *biotechnology, consumer attitudes towards technology, Eurobarometer, genetically modified food, recursive mixed-process model, trust*

De l'impact de la confiance sur le consentement des consommateurs à acheter des aliments génétiquement modifiés : étude empirique à partir d'une enquête européenne

Résumé – De nombreux chercheurs se sont intéressés à expliquer l'acceptation ou l'opposition des consommateurs aux organismes génétiquement modifiés (OGM) à partir de différents facteurs sociaux dans le cadre de modèles de « causalité directe » ou « jointe ». Ce dernier (également appelé « modèle associationniste ») considère les attitudes envers la nourriture génétiquement modifiée comme déterminées conjointement par la confiance et la perception du risque. À partir des données d'une enquête européenne (l'Eurobaromètre 64.3 de 2005), nous développons un modèle récursif à réponse mixte pour établir l'importance de la confiance dans les différentes organisations impliquées dans le débat public sur l'acceptation des aliments génétiquement modifiés de la part des « citoyens ordinaires ». Nous discutons par la suite ce portrait des citoyens européens qui les montre de plus en plus optimistes envers les biotechnologies, bien que largement divisés sur la question. Nous montrons enfin que la pertinence empirique des modèles de causalité directe ou jointe dépend du type d'organisations concernées.

Mots-clés : biotechnologie, attitudes des consommateurs envers les technologies, Eurobaromètre, aliment génétiquement modifié, modèle récursif à réponse mixte, confiance

JEL descriptors: C35, D11, D12, L65

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1. Introduction

The use of biotechnology in production processes is widespread today in a number of sectors, such as pharmaceuticals, agriculture, food-processing, chemistry, environment, cosmetics, energy, etc. While the introduction of biotechnology in pharmaceuticals has been largely accepted, agricultural biotechnologies have triggered off an intense debate since their emergence, and especially with the introduction of the second generation of value-enhanced or nutritionally enhanced genetically modified food (GM food). Perceptions of innocuousness (or lack of the same) have led to a multiplicity of official initiatives on the evaluation of this new technology in several industrialized countries and an important mobilization of those civic associations that influence public opinion (such as consumers' associations, environmental and animal protection associations) (Chaklatti and Rousselière, 2006). In contrast to the environmental protection associations, which were the leaders in the emergence of the debate about genetically modified organisms (GMOs) in Europe, consumers' associations can be considered as the followers, who became involved quite late in the debate. The initial positioning of environmental protection associations such as Greenpeace France, one of the most important actors in the structuring of the debate in France, earned them credibility in the eyes of the public (Todt, 2003; Toke, 2004). Furthermore, while the opposition of the environmental protection associations is founded on disagreement about principles, consumers' associations seem at first sight to be striving for the defense of consumers' interests and in particular for the right of information.

Such mobilization of non-corporate private actors clearly fits into the framework of a controversial or debated universe (Godard, 1998; Boisvert and Vivien, 2005; Chaklatti and Rousselière, 2006): Where stances on public interest issues (environment in this case) are constructed through an interplay among the various actors involving scientific controversy, industrial interests, political stakes, lobby groups and media effects. In such a debated scenario, it is crucial to answer the question about the formation of individual and collective preferences. In this framework, several articles show the diversity of consumers' approval or refusal of biotechnology-based food-products. The determinants of opposition to or acceptance of GMOs seem to be largely linked to individual attitudes and values (Pardo *et al.,* 2002; Bredahl, 2001), where the level of scientific knowledge about biotechnology is of relatively less importance for the formation of individual preferences (Barker and Burnham, 2001; Priest *et al.,* 2003; Sturgis *et al.,* 2005; Gaskell *et al.,* 2004). Finally, the notion of trust seems to be the determining factor in a debated universe, which is characterized by uncertainty and a lack of common knowledge (Boisvert and Vivien, 2005).

In the above context, the present work aims to characterize the position of "ordinary citizens" who are not legitimized either by a specific expertise or by a representative function (Joly and Marris, 2003). The originality of our work, which also represents our contribution to the existing and growing literature, consists of a quantitative test of the two alternative views of the relation between trust and acceptance – "direct causal" or "joint causal" (also referred to as the "associationist" model) – using econometric techniques; and to the best of our knowledge this has never been done before.

The paper is based on a survey of public opinion in Europe on biotechnology. It is organized as follows. The next section contains a literature review, followed by a presentation of the survey data in section 3. Then the model is introduced in section 4, followed by an explanation of the results of the empirical model in section 5. Section 6 discusses and concludes. In terms of the methodology, a recursive mixed process model is retained to test the two alternative views of the relation between trust and acceptance. This approach takes into account both simultaneity and endogeneity risks that lead to biased coefficients. The estimation method is appropriate and consistent for recursive systems in which all endogenous variables appear on the right-hand-sides as observed (Roodman, 2009). The errors of each equation are correlated, sharing a multidimensional distribution. The estimated parameters of trust in the acceptance equation thus constitute an empirical test of the direct causal model, while the correlations of the errors are an empirical test of the joint causal model.

The contribution of our paper can be summarized in terms of its two main results. First, we find support for the direct causal model that insists that trust in scientists, public authorities and industry influences acceptance. In terms of policy formulation, this indicates that an effort to increase trust in these actors would lead to an increase in the acceptability of GM foods. Second, concerning environmental and consumer associations, our econometric model supports both models of causality (direct and joint). It shows that in addition to trust in associations, the attitude of citizens vis-à-vis biotechnology in general influences the level of trust and thereby the acceptability of GM. In policy terms, there are conflicting agendas between various actors (public authorities and associations) in both educating and building awareness in citizens of the potential of biotechnology at large.

2. On the social determining factors of the willingness to purchase GM food: The importance of trust

The attitude of the public towards GMOs has been studied in surveys taking into account socio-demographic variables, the level of knowledge, trust in the information and/or the actions of certain actors, social and political values, perception of the risks and benefits linked to agricultural biotechnology, etc. In this context, there are two types of works: First, there are surveys in experimental economics (Cook *et al.*, 2002; Frewer *et al.*, 2003; Lang *et al.*, 2003; Huffman *et al.*, 2004a, 2004b; Lusk *et al.*, 2004; Noussair *et al.*, 2004; Townsend and Campbell, 2004; Townsend *et al.*, 2004); and second, there are analyses based on national and international surveys (Bredahl, 2001; Pardo *et al.*, 2002; Priest *et al.*, 2003; Gaskell *et al.*, 2004; Poortinga and Pidgeon, 2004, 2005, 2006; Chaklatti and Rousselière, 2006, 2007; Allum, 2007; Barnet *et al.*, 2007; Qin and Brown, 2008; Canavari and Nayga, 2009). Both types of studies show the diversity of consumers' acceptance or rejection of biotechnological food-products. These different methodologies are coupled with a diversity of theoretical models (human capital, conventionalist economics, behavioural economics, and social psychology). Different models of econometric methods are also used for measuring the relationship between social values and acceptability (zero-order and partial correlations, linear and logistic regressions, factorial analysis, ANOVA and MANOVA, structural

or simultaneous equations modelling). While the results are influenced by the impact of knowledge and risk perception, trust is unanimously considered to be a key factor.

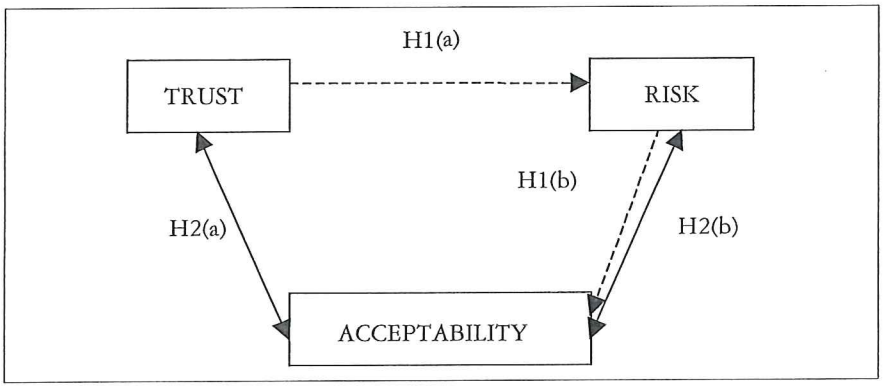
Some surveys carried out in Europe (Bredahl, 2001; Pardo *et al.*, 2002; Gaskell *et al.,* 2004) and in the United States (US) (Onyango *et al.*, 2004) on the importance of the perceived risks and benefits indicate that consumers are very sceptical about the use of GMOs in food products. They consider that the new technology involves a high element of risk. These consumers link the risk with the intended benefits of GMOs and they are aware that zero risk concerning the impact of GMOs does not exist. Attitudes towards GMO use in food products are explained by the risks as well as the benefits associated with the technology. As Gaskell *et al.* (2004, p. 191) point out, there is no direct relation between risk perception and opposition, but rather a plurality of possible attitudes, differing in respect of the key social and cognitive resources that may influence consumers' views of GM food. In general, the level of scientific knowledge in biotechnology is of relatively less importance for the formation of individual preferences (Priest *et al.*, 2003; Gaskell *et al.*, 2004; Sturgis *et al.,* 2005; Chaklatti and Rousselière, 2006, 2007; Bukenya and Wright, 2007). On this last point, according to Marris (2001) and Gaskell *et al.* (2004), the general argument (which states that a higher level of knowledge would result in a better acceptance of biotechnology) would reveal a misunderstanding about the way in which consumers take decisions, as they take into account other factors. Moreover, there is a huge disagreement on the link between knowledge and scientific attitudes (Gaskell *et al.,* 2004). This suggests, as noted by Barker and Burnham (2001), that consumer behaviour is determined less by how much they know and more by what they believe.

Trust has therefore been increasingly identified as the key issue that decision makers involved in the management of risks have to address. Indeed different authors put forward the notion of trust (Cook *et al.*, 2002; Todt, 2003; Priest *et al.,* 2003; Huffman *et al.*, 2004a, 2004b; Lusk *et al.,* 2004; Poortinga and Pidgeon, 2004, 2005, 2006; Allum, 2007; Barnett *et al.*, 2007; Qin and Brown, 2008; Canavari and Nayga, 2009) as a determining factor in defining the position of individuals concerning GMOs applied to agriculture, in a different manner. According to Todt (2003) and Priest *et al.* (2003), the controversy over the use of certain technologies is first a sign of the trust gap between the actors. The usual arguments of scholars and political parties are that if citizens trusted scientists and public authorities, they would have little reason to oppose technological developments such as GM food (Gaskell *et al.*, 2004). In general, many studies show that trust in scientists (Chaklatti, 2006; Allum, 2007; Canavari and Nayga, 2009), government authorities (Barnett *et al.* 2007; Chaklatti 2006; Qin and Brown 2008) or industry (Huffman *et al.,* 2004a) has a positive impact on the willingness to purchase GM food. On the contrary, trust in environmental associations (Huffman *et al.,* 2004a; Chaklatti and Rousselière, 2007) results in a lower acceptability of GM food. This ties in with the "trust gap" result of Priest *et al.* (2003), which explains the difference in the consumption of biotechnological products in Europe and the US by the higher trust in Europe in consumers' and environmental protection associations, and the parallel higher trust in the US in industrial and agbiotech firms rather than education and knowledge.

Accepting that there is empirical evidence that trust and GM food acceptability are closely correlated, there are two alternative competing views (Eiser *et al.*, 2002; Poortinga and Pidgeon, 2005): the associationist and the causal views. The causal model of trust is the most common interpretation of the generally strong relationships between trust and GM food acceptability. Huffman *et al.* (2004a) developed such a model inspired by Becker (1996). The latter suggests a formal model of individual preferences or tastes, which takes into account the "social capital" (acquired through relatives and participation in social networks) and the "personal capital" (acquired by the individual through education and experience) (Becker, 1996, pp. 7-18). Trust, seen as a function of these two types of capital, has then an influence on the choice between different types of goods (for instance GM and regular food). The same individual holds at the same time different levels of trust in different actors and it is this, which influences the final decision. If an individual increases his trust in the information coming from environmental protection groups or loses trust in the information coming from agbiotech business, this contributes to lower his marginal utility of GM products (by hypothesis). The marginal rate of substitution of the consumer between GM and regular food decreases. At given relative prices, the consumer will purchase more regular food products and lower his consumption of GM food products. Therefore researchers use standard linear or logistic regressions with trust as an independent variable to predict the level of the willingness to purchase or accept GM food in general or some special GM varieties (*e.g.* Onyango *et al.*, 2004; Canavari and Nayga, 2009). According to this schema, two causal relationships can be identified. Trust determines risk perception (H1(a)), which determines acceptability (H1(b)) (figure 1).

According to the associationist view, trust, acceptability and risk perception could well be indicators or expressions of a more general attitude toward a technology (H2(a) and H2(b)) than social psychology theories (Eiser *et al.*, 2002; Poortinga and Pidgeon, 2005; Boecker, 2008) or conventional economics (Chaklatti and Rousselière, 2006) would lead us to presume. There is a link between trust, risk perception and acceptability, but trust and perceived risk are both independent indicators of attitude. Risk judgements appear to reflect broader public stances on highly politicised issues. The way in which people interpret evidence on such issues and form judgments about

Figure 1. Associationist and causal views of trust



the acceptability of risk is likely to be influenced by these broader views. For Boecker (2008), empirical evidence supporting the "associationist view" would question efforts to increase the acceptability of GM foods through increasing trust in public bodies and industries. As we do not have to assess causality but association [1], this model is tested with partial and zero-order correlation: *"controlling for acceptance should reduce or eliminate any relationship between trust and perceived risk"* (Eiser *et al.,* 2002, p. 2426).

Drawing on the results of this literature review, this paper will consider trust in the actors involved in the public debate on GMOs as a determining factor in their acceptability. Thus we will ensure that the methodology employed allows us to test the two models of trust simultaneously, while controlling for trust in the various organizations involved in the public debate.

3. Presentation of the survey data

The data used are taken from the special European survey "Eurobarometer 64.3" dealing with "Foreign Languages, Biotechnology, Organized Crime, and Health Items" (Gaskell *et al.,* 2006). The special Eurobarometer reports are based on advanced thematic studies carried out for the European Commission or other European institutions, and integrated into the waves of the survey of the standard Eurobarometer. Carried out in November and December 2005, Eurobarometer 64.3 covers the population of the respective nationalities of the European Union Member States, resident in each of the Member States and aged 15 years and over. 25000 individuals from 25 countries were thus questioned. Our study is based on the sample of the 12 320 individuals who had to answer the biotechnology module.

In our analysis, we have paid attention to the variables usually employed in the literature. These include socio-demographic indicators (age, age at the end of formal education, gender, professional status, place of residence, etc.), individual values (political and religious stance, interest in science and politics) and variables concerning the debate on biotechnology (trust, knowledge, information). For "trust", the question posed is: *"Do you trust the information on modern biotechnology coming from the following sources?"*. Each time we thus obtain a qualitative dichotomous variable with the modalities "trust" (mentioned) and "no trust" (not mentioned). The list of variables obtained is relative to the level of confidence in some of the organizations [2]. The possibility of answering *"do not know"* is thus offered as well as the possibility of spontaneously answering *"none of these"*. A scale based on these various trusts has a weak Cronbach's Alpha (0.401), which allows us to suppose that very different social dynamics are at stake (trust cannot be considered as an one-dimensional latent variable). According to Gaskell *et al.* (2006), the 2005 survey data do not support the

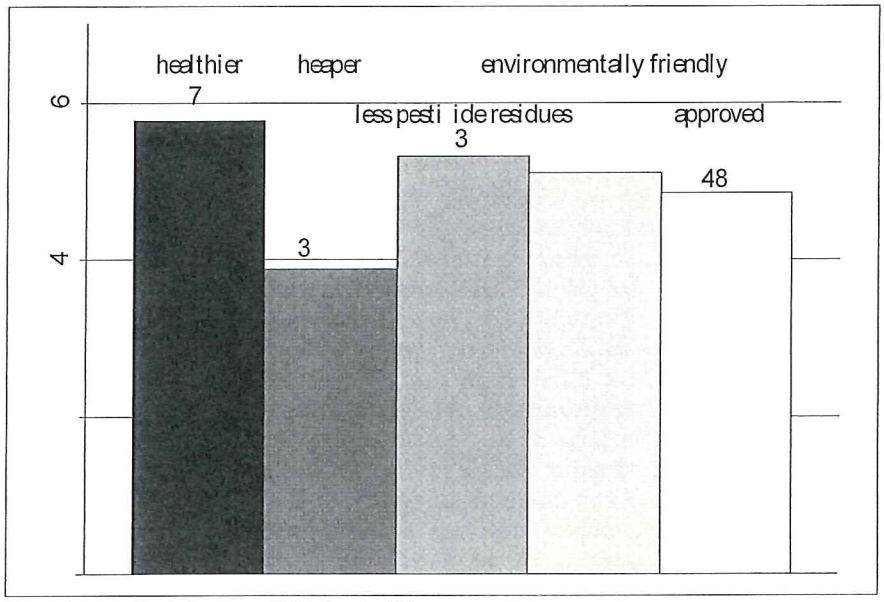
[1] There is a difference on this point between the seminal work of Eiser *et al.* (2002) (association) and the interpretation of Poortinga and Pidgeon (2005) (causality).

[2] "Consumer organizations", "environmental organizations", "animal welfare organizations", "the medical profession", "farmer organizations", "religious organizations", "national government bodies", "international institutions (not companies)", "industry", "universities", "political parties", "television and newspapers".

laim that there is a risis of trust in the a tors involved in iote hnology in Europe Trust in every sour e of information shows su stantial improvements sin e the first Euro arometer on iote hnology in

e also reated new varia les on erning the willingness to pur hase GM food and knowledge of iote hnology figure Five questions were asked a out the reason for pur hasing GM food with three possi le modes of response "yes" "no" "do not know" [3] Based on the positive responses to these five questions we thus onstru ted a s ale of a eptan e going from "total opposition" to "total a eptan e" Cron a h's Alpha for this s ale is 7 The high relia ility allows us to assume that this s ale is a good measure of the latent varia le "a eptan e of GM food" A ording to Gaskell et al 4 the division ased on a "total opposition"/"at least one reason to uy GM Food" di hotomy is one that dis riminates most etween the two groups thus reated In effe t a ross all the ountries the mean for the pur hase s ale amongst the potential uyers is 3 6 This relatively high value indi ates that the pu li is split on this issue "The non uyers operate a total veto ut on ea threshold of minimal a epta ility is rea hed then people are in lined to find a num er of reasons a epta le for uying GM foods"

Figure I would uy geneti ally modified food if...



Notes Cron a h's alpha = 7 high relia ility
At least one reason to uy GM food 64

[3] "I would uy GM food if it were healthier" "I would uy GM food if it ontained less pesti ide residues than other food" "I would uy GM food if it were grown in a more environmentally friendly way than other foods" "I would uy GM food if it were approved y the relevant authorities" "I would uy GM food if it were heaper than other foods"

(Gaskell *et al.*, 2006, p. 24). But as Gaskell *et al.* (2006) point out in their latest survey on Europeans attitudes toward biotechnology, in order to take account of the growing heterogeneity of the European Union, the analysis should be based on the scale of acceptance. We thus established a scale of acceptance (ACCEPTANCE) of the food use of GMOs.

The health and environmental related reasons for buying GM food seem to be the elements influencing the pro-GMO choice: 57%, 53% and 51% of Europeans would buy GM food if it respectively were healthier, contained less pesticide residues and were more environmental friendly. While environmental benefits attract more potential purchasers than non-purchasers, European opinion is clearly split on this. Neither approval by the relevant authorities nor lower prices appear to be persuasive reasons in people's choice intentions: "*While economics tells us that price is a key determinant of people's actual choices, in this hypothetical situation some may be responding as citizens rather than as consumers*" (Gaskell *et al.*, 2006, p. 13).

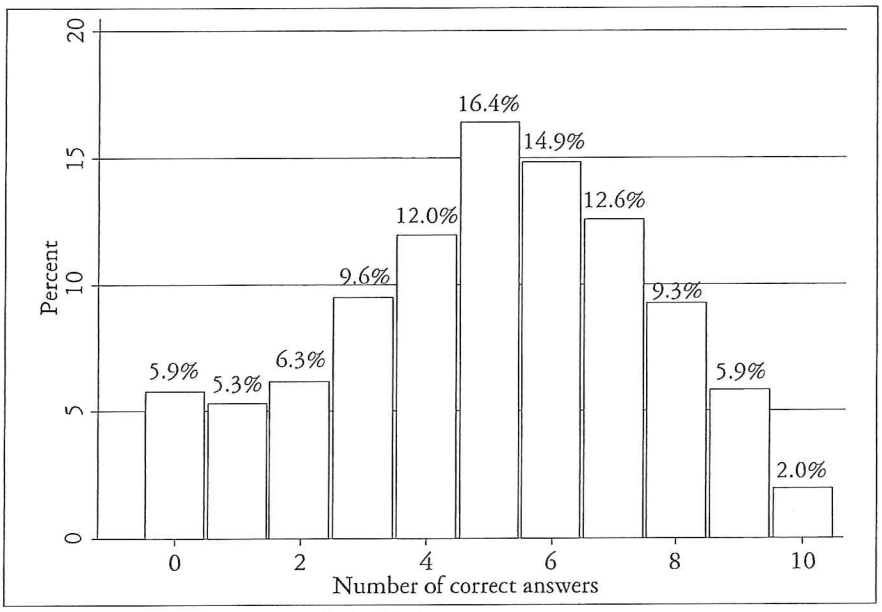
A variable was created concerning knowledge of biotechnology. Questions concerning the use of biotechnology had the goal of measuring the real knowledge of individuals. A scale taking up the 10 questions can thus be constituted [4]. We thus obtain a reliable scale (Cronbach's Alpha = 0.711) providing the number of right answers (figure 3). Only 2% of the European population respond correctly to all questions and 45.5% to more than five questions. But since 1996, there has been a constant increase in the proportion of Europeans' knowledge of genetics and biotechnology. Gaskell *et al.* (2006) propose two different explanations: a generation effect (young people may have been taught these topics at school) or a period effect (the population as a whole is learning more about these emerging areas).

We also find small but significant correlations between willingness to purchase GM food and various sources of information, suggesting that these items relate to each other [5]: People with a willingness to purchase GM food are more likely to trust the medical profession ($r = 0.10$; $p < 0.01$), national and international governments and institutions ($r = 0.08$ and 0.07 respectively; $p < 0.01$), the European Union ($r = 0.11$; $p < 0.01$), industry ($r = 0.04$; $p < 0.01$) and universities ($r = 0,05$; $p < 0,01$); they have less trust in consumer, environmental and animal welfare associations ($r = -0.03$, -0.05 and -0.04 respectively; $p < 0.01$); knowledge in biotechnology and willingness to purchase GM food are also positively correlated ($r = 0.05$; $p < 0.01$).

[4] "It is possible to find out in the first few months of pregnancy whether a child will have Down's Syndrome", "It is not possible to transfer animal genes into plants", "Human cells and human genes function differently from those in animals and plants", "Ordinary tomatoes do not contain genes, while genetically modified tomatoes do", "Genetically modified animals are always bigger than ordinary ones", "Embryonic stem cells have the potential to develop into normal humans", "By eating a genetically modified fruit, a person's genes could also become modified", "More than half of human genes are identical to those of a chimpanzee", "Yeast for brewing beer or making wine consists of living organisms", "The cloning of living things produces genetically identical copies".

[5] When measuring associations between dichotomic variables, one must pay attention to the fact that Pearson correlations are by nature limited to a range largely smaller than – 1 to 1.

Figure 3. Knowledge about biotechnology



Note: Cronbach's alpha = 0.711 (good reliability)

4. The econometric strategy: A recursive mixed process model

The relationship between consumer characteristics and consumer willingness to purchase GM food is examined through an institutionalist econometric model of consumption that is compatible with the various theories reviewed previously. As Hendry (2000) suggests, our econometric model must take into account the fact that the data used cannot be treated as if they were generated under controlled conditions, and that we have to consider the existence of structural breaks and the intrinsically dynamic nature of social reality (Pratten, 2005). Fixed effects and endogeneity are therefore two issues that our econometric model must deal with. Finally, as in the majority of cases, it is not possible to preview exactly how each individual will behave; it is more reliable to estimate a probability, through a logistic model, that an individual with some attributes will choose a given alternative.

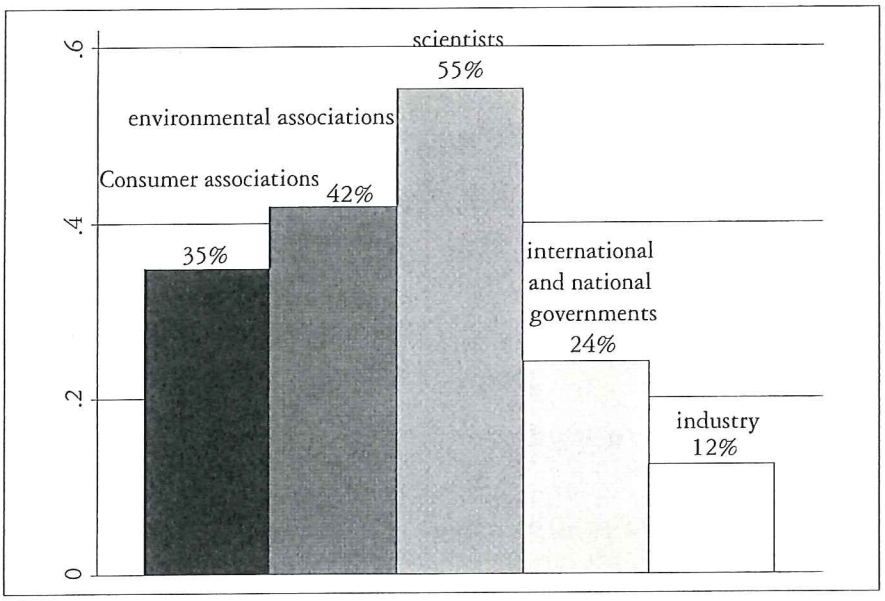
To study the relationship between trust and acceptability, we concentrated on five categories that are the most important in this debate on GMOs (figure 4): Trust in the information on biotechnology furnished by environmental associations, by consumer associations, by the agbiotech industry, by the scientists, and finally by public authorities (international and national governments). As shown by a hierarchical cluster analysis [6],

[6] The hierarchical cluster analysis, using Ward's method, is not reported here. The results are strictly comparable to Chaklatti and Rousselière (2006, 2007). This analysis is available upon request.

scientific and medical professions have a tendency to converge. Grouped together under the label of "scientists", this category is the must trusted by the Europeans (55%). International and national governments on the one hand and industrial and farmers' organizations on the other hand ("industry") follow the same tendency, while being clearly distrusted (only 24% and 12% respectively of European citizens trust them to tell the truth about modern biotechnology).

To analyze these data further, different methods of limited dependent variable regression could be used. However, there is a risk – namely that we might get biased coefficients – as in the present case we could fear the simultaneity of decisions (trust and acceptability); the responses to the different questions are not independent to one another. Unfortunately, this issue was not correctly taken into account by previous research (*e.g.* Huffman *et al.*, 2004a; Onyango *et al.*, 2004; Townsend and Campbell, 2004; Canavari and Nayga, 2009), which was only based on the causal model of trust. For example, Onyango *et al.* (2004) estimated the impact of trust in scientists, industrialists or the medical profession with a dummy independent variable and claimed that there was no effect. By contrast, it is reasonable to suppose that the determining factors, both observable and unobservable, of a trust type and willingness to purchase are variables that could potentially explain the other types of trust. A simultaneous discrete choice model, or multivariate discrete choice model (Greene, 2009), may be a better indicator of the real consumer behaviour. To take into account this simultaneity, which induces endogeneity risks that lead to biased coefficients (Wooldridge, 2002), we estimate a conditional recursive mixed-process model (Roodman, 2009). Whereas multivariate probit model allows only dummies to be used

Figure 4. "Do you trust "..." to tell you the truth about modern biotechnology?"



as dependent variables (Cappellari and Jenkins, 2003, 2006), a mixed-process model has a variety of link functions for limited dependent variables. This model gives us two indications: The coefficient *rho* of correlation between residuals to assess the force of association of the different variables (once controlled by a set of other variables); and the trust coefficients in the acceptance equation as an estimation of the impact of a given trust on willingness to purchase GM food. The former is a test of the associationist model and the latter a test of the causal model. Therefore this econometric strategy clearly fits not only with methodological issues but also with our theoretical framework presented in the first part of this article. While a multivariate response model based on a system of seemingly unrelated equations can only test an associationist model of trust [7], with a recursive mixed process model, we are indeed in a position to test simultaneously associationist and causal models of trust.

We do not use structural equations modelling. As the controversy between economists and statisticians shows (Heckman, 2008), this modelling is possible only if there is a consensus on a theoretical model (the first step of the scientific inquiry described by Heckman). But if we face dissensus, as Karl Popper wrote in the *Open Society*, *"we should not attempt to cross our bridges before we come to them"* (1995, p. 23). We need an econometric strategy with as few constraints as possible in order to test the concurrent models. If we agree with Pearl (2009), a structural approach to estimating causality typically features stronger and untested assumptions. Then it is only when a theory has been corroborated that a structural econometric approach is valid and more powerful (especially for forecasting).

We thus select the six variables y_1 (acceptance scale – labelled ACCEPTANCE), y_2 (trust in the information on biotechnology given by environmental associations – labelled TRUSTENVI), y_3 (trust in the information given by consumers' associations – labelled TRUSTCONSO), y_4 (trust in the information on biotechnology given by the agbiotech business – labelled TRUSTINDUS), y_5 (trust in the information on biotechnology given by scientists – labelled TRUSTSCIENCE) and y_6 (trust in the information on biotechnology given by public authorities – labelled TRUSTPUBLIC).

The system of equations to be estimated is then given by:

$$
\begin{cases}
y_1^* = \alpha_1 + \sum_{j=2}^{6} \beta_1^j \cdot y_j + \pi_1 \cdot X + \lambda_1 \cdot V + \mu_1 \cdot C + \varepsilon_1 \\
y_2^* = \alpha_2 + \pi_2 \cdot X + \lambda_2 \cdot V + \mu_1 \cdot C + \varepsilon_2 \\
y_3^* = \alpha_3 + \pi_3 \cdot X + \lambda_3 \cdot V + \mu_2 \cdot C + \varepsilon_3 \\
y_4^* = \alpha_4 + \pi_4 \cdot X + \lambda_4 \cdot V + \mu_3 \cdot C + \varepsilon_4 \\
y_5^* = \alpha_5 + \gamma_{\pi 5} \cdot X + \lambda_5 \cdot V + \mu_4 \cdot C + \varepsilon_5 \\
y_6^* = \alpha_6 + \pi_6 \cdot X + \lambda_6 \cdot V + \mu_5 \cdot C + \varepsilon_6
\end{cases}
$$

[7] Equations in a Seemingly Unrelated Regressions (SUR) system seem unrelated in the sense that non-endogeneous variables appear on the right side of other equations, but their errors can be correlated, sharing a multidimensional distribution.

with six latent variables $y_1^*, y_2^*, y_3^*, y_4^*, y_5^*, y_6^*$

$$y_1 \quad p \text{ if } \tau_{p-1} < y_1^* < \tau_{p-1}, \text{ with } p \quad 0,\ldots,5, \ \tau_{-1} \quad -\infty \text{ and } \tau_5 \quad \infty$$

$$y_j \quad 1 \text{ if } y_j^* > 0 \text{ and } y_j \quad 0 \text{ if } y_j^* \leq 0 \text{ with } j \quad 2,\ldots,6$$

X a vector of socio-demographic variables, V a vector of variables of social values and attitudes and C a vector of country dummies variables. These vectors are identical in each equation.

$\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, \varepsilon_5, \varepsilon_6$ are six error terms distributed according to a multivariate normal distribution, with rho_{ij} the correlation between ε_i and ε_j[8].

We choose the X, V and C vectors according to previous studies: the different socio-demographic variables (age, gender, education, current socio-professional status, marital status, location of residence), variables of values (political stance, religion, variables in relation to the GMO debate), as well as dichotomous variables of countries as a control on country effect.

This system includes an ordered probit (acceptance scale) and five binary probits (trusts). It is estimated according to the method of simulation of maximum likelihood (as the estimation implies the calculation of a sextuple integral within the likelihood function). The Geweke-Hajivassiliou-Keane (GHK) smooth recursive simulator (Hajivassiliou, 2000; Greene, 2008) exploits the fact that a multivariate normal distribution function can be expressed as the product of sequentially conditioned univariate normal distribution functions. Instead of an evaluation of multivariate integrals, the GHK simulator only requires draws from truncated normal distributions and the evaluation of univariate integrals.

It corresponds to the *cmp* procedure of *Stata* developed and implemented by Roodman (2009), based on previous work of Cappellari and Jenkins (2003, 2006) and Gates (2006)[9]. The use of the GHK simulator implies that results depend on a number of random draws used to calculate the simulated likelihood function. However, when the number of observations is high, convergence can be achieved, with some loss in precision, with remarkably few draws per observation, as few as five when the sample is 10 000 (Cappellari and Jenkins, 2003; Roodman, 2009). Furthermore, draws variables based on Halton sequences are shown to perform better than those based on a pseudo-random draw (Cappellari and Jenkins 2006). Consequently the choice of 10 draws from Halton sequences allows us to be relatively confident in the estimated parameters.

[8] The usual assumption that ε is independently and identically distributed is clearly violated here, as the observations are clustered in countries. However with a small number of clusters (lower than 50) and very unbalanced cluster sizes, the cluster-robust standard error can be more biased than the usual standard error.

[9] See Hammond (2010) for a three simultaneous equations model included a censured regression with two selection equations.

5. Results

The results of the mixed recursive model are presented in table 1. The loglikehood ratio (LR) test of rho_{ij} (positive) allows us to justify the estimation of this mixed process model and not of six independent equations: The null hypothesis (H0) of independence ($\forall i, j$ 1,...,6 and $i \neq j$, rho_{ij} 0) can be rejected (p-value < 0.0001). Moreover, the coefficients rho_{ij} (the correlation between the terms of errors in each one of the equations) are significant and of interest: The unobserved variables influencing the willingness to purchase GM food are positively correlated with the unobserved variables influencing the trust in environmental and consumers' associations. Trust and acceptability may be caused by a third variable or a more general attitude toward biotechnology. This supports the associationist view of the relation between trust in associations and acceptance. On the other hand, this theory is invalid for the cases where rho_{ij} is not significant: The unobserved variables influencing acceptability appear not to be correlated to the unobserved variables influencing the trust in scientists, public institutions and industry. All types of trust are positively correlated with each other. The model with countries fixed effects has a Bayesian information criterion (BIC) and Aikake information criterion (AIC) largely lower than the model without fixed effects, suggesting the former is preferable [10]. The trust parameters estimated are in all cases significant, which is a validation of the causal view of trust.

From the above explanation of these results, we can conclude that it is not exactly the same variables that significantly influence the different dependant variables. Concerning the socio-demographic variables, the willingness to purchase is positively influenced by age: This relationship can be modelled in the form of a quadratic equation. The acceptability decreases strongly in relation to age but in a successively slower manner. The marginal propensity to trust the information provided by environmental and consumer associations increases among women and consequently the marginal propensity to trust public authorities and to accept GM food is lower. The level of knowledge influences positively all the dependent variables (with the exception of the trust in the information provided by the industry). The variables concerning the political scale influence the different dependant variables. Indeed, in relation to the people subscribing to the ideology of the left, those more to the right or not situated on the political scale at all, tend to be less confident in the information provided by environmental associations. The estimation emphasizes the "left" opposition to GMOs, which is commonly found (see Chaklatti and Rousselière, 2006, 2007). However, another type of opposition to GMOs can be identified. The people who oppose GMOs while they do not trust any of the diverse organizations are people who are indifferent to scientific arguments. In other words, there is a type of opposition not keen on scientific information.

[10] For the model with countries fixed effects, AIC=103 195.6 and BIC=105 510.3; for the model without countries fixed effects AIC=105 922.3 and BIC=107 079.7.

Table Results of the mixed recursive model

	ACCEPTANCE	TRUSTCONSO	TRUSTEN I	TRUSTSCIENCE	TRUSTPUBLIC	TRUSTINDUS
TRUSTCONS	– 8**					
TRUSTEN I	– 36*					
TRUSTSCIENCE	37***					
TRUSTPUBLIC	36***					
TRUSTINDUS	**					
AGE	– 8***	**		– **	–	– 7
AGE	***	– **	– 6	**		3
WOMAN	– 6 ***	8*	***	*	– 6 ***	
MARRIED	–	– 6 **	–	– 3	78***	–
EDUC 6–		**	***	–	77**	– 8
EDUC +	– 7***	**	**	–	***	– 77
EDUCSTILL	– 3	3	8 ***	3***	6***	–
SCALEKNOWLEDGE	***	***	3 ***	***	***	7
TALKEDBIOTECH	– 68***	86***	***	**	8***	– 6 *
OFTENINTPOLITICS	3 ***	88***	8 ***	8**	36***	3
SOMEINTPOLITICS	6 ***	***	***	3 ***	***	
RAREL INTPOLITICS	6***	6	–	***	***	
OFTENINTSCIENCE	6***	3 ***	6***	***	3 ***	**
SOMEINTSIENCE	6 ***	7***	3 ***	8 **	3	76
RAREL INTSCIENCE	***	6 ***	63***	8***		3

Table Results of the mixed recursive model continued

	ACCEPTANCE	TRUSTCONSO	TRUSTEN I	TRUSTSCIENCE	TRUSTPUBLIC	TRUSTINDUS
NORELIGION	–	– 66**	– ***	– 3	– 77**	– 86**
POLITICALCENTER	**	– 88***	– 6 **	7*	– 37	6
POLITICALRIGHT	63**	– 3***	– 6***	3***	–	3**
POLITICALREFUSALDK	– ***	– 7 ***	– 87***	– 7***	– **	
INTERCEPT	τ – 7 *** τ – 8 ** τ3 – τ τ 6 ***	– ***	– 63***	– 3 3***	– 73***	– ***
Log pseudo likelihood			– 8 8			
LR test of Rho$_{ij}$			67 ***			

Rho$_{ij}$	ACCEPTANCE	TRUSTCONSO	TRUSTEN I	TRUSTSCIENCE	TRUSTPUBLIC	TRUSTINDUS
ACCEPTANCE	–	3 **	3*	– 37	–	
TRUSTCONSO		–	37 ***	7***	***	63***
TRUSTEN I			–	***	6 ***	***
TRUSTSCIENCE				–	73***	***
TRUSTPUBLIC					–	6 ***
TRUSTINDUS						–

Note *** ** and * indicate significance at the and levels Countries and communities fixed effects are not reported

Table 2. Marginal effects of trust variables on acceptance

	$\frac{\partial \text{ Probability of a level of acceptance}}{\partial \text{ TRUST}}$				
Level of acceptance	TRUSTCONS	TRUSTENVI	TRUSTSCIENCE	TRUSTPUBLIC	TRUSTINDUS
Y1=0	0.059	0.050	−0.120	−0.111	−0.040
Y1=1	0.004	0.003	−0.007	−0.009	−0.003
Y1=2	0.001	0.001	−0.002	−0.005	−0.001
Y1=3	−0.001	−0.001	0.003	0.000	0.000
Y1=4	−0.008	−0.006	0.015	0.011	0.005
Y1=5	−0.054	−0.047	0.112	0.113	0.040

Note: Marginal effects evaluated at the mean for each level of acceptance and for a discrete change of trust

In order to estimate the impact of trust on acceptance, we can compute the marginal effects at the mean (MEM) for the various level of the dependant variable (table 2). According to Greene (2008), MEM is asymptotically identical to average marginal effect (AME). In our case, AME the for binary variable can be interpreted as an average treatment effect (ATE) or an average causal effect (ACE), the average effect of trust on the whole population (Wooldridge, 2002).

We deduce that trusting environmental associations leads to a lowering of 4.7% in the probability of having five reasons for purchasing GM food and a rise of 5% in the probability of having no reason. Our conclusions confirm those of Huffman (2003) on the important impact of trust in environmental associations. The impact of trust in consumer associations is very similar (−5.4% in the probability of having five reasons and + 5.9% in the probability of having no reason). On the other hand, trusting the scientists, the public institutions or the industrialists leads to a rise of the probability of having five reasons for purchasing GM food (by 11.2%, 11.3% and 4.0% respectively) and a lowering of the probability of having no reason (by 12.0%, 11.1% and 4.0% respectively).

6. Discussion and conclusion

This study is based on results from a European survey that finds an increasing optimism in the growth and acceptance of GM food. The main aim of the article was to evaluate two different perspectives on the relation between trust and acceptability. Similarly to Eiser *et al.* (2002), we find support for a complex view of trust that can reconcile two apparently contradictory viewpoints.

Understanding the basis of public trust is essential for explaining the variation in the public perception of technological risk. Trust in the information given by certain actors (such as associations, scientists, industrialists and governments) is therefore a determining factor in explaining the differences in attitudes concerning GM food

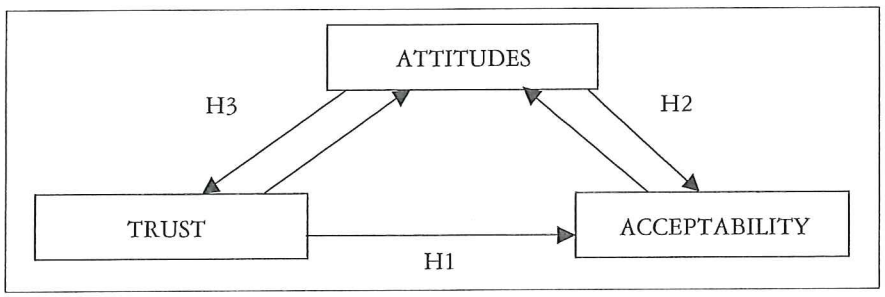
Table 3. The validation of the theories

	View of the relation between trust and acceptance	
	Causal	Associationist
TRUSTCONS	Yes (in part)	Yes
TRUSTENVI	Yes (in part)	Yes
TRUSTSCIENCE	Yes	No
TRUSTPUBLIC	Yes	No
TRUSTINDUS	Yes	No

consumption. The causal view is validated in every case (table 3) but leaves unexplained the correlation between the error terms in the acceptance equation and in some of the trust equations. Our econometric model is also supportive of an associationist view that considers trust in associations to be a consequence of acceptability (but not for the other types of trust). If we agree with the radical falsificationism of the "first Popper", any theories that are not full corroborated are false. Consequently both theories are to be rejected. But according to the sophisticated falsificationism of the "second Popper", well described by Lakatos (1978), the objective of the science is to arrive at an evolutionary process whereby theories become less bad. Consequently, both theories may not be entirely rejected but integrated in a more general approach. The mixed process model is justified if we consider a complex view of trust, *i.e.* a causality oriented system (figure 5). Trust and acceptability may be caused by a more general attitude toward biotechnology (maybe with feedbacks) (H2 and H3) in a system with a causality oriented from trust to acceptability (H1). This general model includes causal and associationist models as special cases.

This leads to important theoretical propositions in terms of economic analysis. It is necessary to take into account values and perceptions in the economic theory of the consumer, both as proposed by the human capital or the conventionalist approaches. Our empirical analysis can then be understood as a corroboration of such theoretical analysis. Trust has rightly assumed enormous prominence as an explanatory concept in relation to dissent and conflict over the development trajectory of a wide range of

Figure 5. A complex view of trust



technologies. Consideration of the importance of a belief in public efficacy would potentially seem to be a valuable complement to this view, and in particular to the recent work on critical trust (Barnett *et al.*, 2007). In terms of policy formulation, our analysis indicates that an effort to increase trust in scientists, public authorities and industry would lead to an increase in the acceptability of GM foods. There is a conflict between these actors and the associations in educating and building awareness in citizens on the potential of biotechnology at large.

Our work confirms the results of different studies, those using the same type of data (transnational surveys including the latest Eurobarometer) and those using other methodologies, on the importance of individual values and attitudes and of the participation in certain social networks, or "the importance of general value orientations or worldviews" (Pardo *et al.*, 2002, p. 9). However, compared with the European situation in 2002, there are some minor changes in the "associations trust effects". The strong negative impact of trust in environmental associations on willingness to purchase GM food decreases while at the same time the negative impact of trust in consumer associations increases.

Further research will need to take into account the problems caused by the European Union heterogeneity. According to Gaskell *et al.* (2006), the new EU10 countries are somewhat different to the EU15 countries in 2005: Science has not achieved much penetration in public awareness in the new Accession States; the people in these countries are relatively more optimistic about the contribution of technology to society, and are just as supportive of medical, industrial and agricultural biotechnologies; and finally they also have greater trust in actors and institutions involved in science and technology. The next step in this research study is to take into account both endogeneity and the institutional effect. Because of the increasing heterogeneity of the European Union, the impact of trust may vary according to institutional variables (rejection of hypotheses of identical coefficients). Additionally, fixed effects models must be replaced by random effects models estimated according to multilevel multi-process modelling (combining multilevel analysis and simultaneous equations modelling) (Goldstein, 2003; Steele *et al.*, 2007). To further strengthen the results of this study and to confirm the same, it would be necessary to have subjective scales of trust in one actor of the debate (which would then provide a scale of "trust gap" at the individual level).

Based on the Eurobarometer, which is a face-to-face survey, our work may undermine some economic factors and underestimate some social factors of the acceptability of GM food. We may suspect that the hostility of the "citizen" becomes attenuated when he is placed in the role of a "consumer" (Noussair *et al.*, 2002). It is quite possible that their valuations of the GM products would change if prices were different. Therefore experimental economics, which focuses on price variations for a small non-representative sample, and cross-national surveys, which focus on values and socio-demographic variables for large samples, are clearly two complementary methods that help us understand the main factors of the willingness to purchase GM food. Micro-simulation, based on behavioural hypotheses confirmed by experimental economics and applied to a representative sample of the population, may be a very promising direction for future research.

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