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Are perceptions of ‘risks’ and ‘benefits’ of genetically modified food (in)dependent?

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Abstract

Although previous research has revealed evidence of European Union (EU) citizens’ sceptical attitudes towards genetically modified food, there has been a limited focus on how individuals learn about the risks and benefits of GM food, along with the influence of information sources on the formation of both risk and benefits perceptions. Following a rational learning model, we examine the determinants of risk and benefit perceptions. In doing so, we hypothesize that risk and benefits perceptions are an expression of a latent and unobserved variable and thus we test whether perceptions of risk and benefits are simultaneously determined. We employ a UK sample of the Eurobarometer survey 52.1 for 1999 and we employ several model specifications that account for simultaneity and endogeneity, such as the two-stage least squares (2SLS) and the three-stage least square (3SLS) regressions. Our results indicate that risks and benefits perceptions are not independent and appear both endogenously and simultaneously determined. Furthermore, the impact of information determinants for risks and benefit learning processes are specification dependant.

Keywords: GM food; Risks perceptions; Benefits perceptions; Three-stage least squares (3SLS) model

1. Introduction

Most individuals do not possess ‘sufficient knowledge’ on the risks and benefits of new and unfamiliar technologies such as Genetically Modified (GM) food (Costa-Font & Mossialos, 2005; Gaskell et al., 1997). However, despite this fact they are inclined to make decisions on the desirability of their commercialisation and development (Gaskell et al., 2004). Individuals’ exposure to information signals on such technologies comes from a variety of information sources, some outside individuals’ control—some of which must have a genuine effect in shaping individuals’ perceptions of benefit—or usefulness—and risk—or expected harm, that may ultimately determine product acceptance. Given that the learning process of both the ‘potential risks’ and ‘potential benefits’ of such products is determined by multiple information sources, it is therefore important to scrutinize how individuals form their perceptions. One way to do this is to investigate individuals’ characteristics associated with information channels. This would allow us to better represent expected behavioural reactions[1] to risk information, which would be useful when designing market regulations and risk communication campaigns.

Prior literature on risk perceptions suggests that individuals are subject to cognitive biases (Slovic, 1987), so

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[1] This assumes that individuals react to the provision of new information.

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that perceived risks are often inconsistent with objective risk information provided to individuals. Several explanations have been given for this, for example the presence of some irrationality in individuals' behaviour (Arrow, 1982) and a lack of perfect information (Viscusi, 1990). However, these findings apply to those areas where subjective risk perceptions can be estimated and compared to 'objective' risk information (e.g., due to the existence of epidemiological evidence). One of the areas where it is not possible to undertake straightforward comparisons between objective and perceived risks is the area of new technologies, and particularly food biotechnology. In this case the communication of the risks and benefits is hardly ever complete and is normally affected by 'scientific uncertainty' (objective information is therefore missing) on the expected future effects. Moreover, while new modified products can replace or improve the quality of some existing goods they may also portray new potential risks; although how people weigh any appreciable quality improvement against potential risks is still an open research question. A widespread explanation is that individuals are expected to resolve their perceptions of uncertainty or risk through learning processes, which are conventionally conceptualised using a simplified Bayesian learning model (Viscusi, 1990). It is assumed that independent information channels produce signals on the product qualities that are weighted either as positive (beneficial) or negative (risky) in the information acquisition process (Benjamin & Dougan, 1997; Hakes & Viscusi, 1997; Viscusi, 1992). Thus, the final perception of risks and benefits is the result of some aggregation of such information.

The aim of this paper is twofold. Firstly, we examine whether the perceptions of the risks and benefits of GM food are independent and can be independently estimated. That is, whether risk and benefit perceptions are likely to simultaneously determine each other so that we are able to test whether risk perceptions could be an expression of lack of benefits (and vice versa). Secondly, we identify the effect of individual characteristics associated with specific information sources that presumably influence individuals' learning about the risks and benefits of GM foods. We use a UK sample from the Eurobarometer survey 52.1 in 1999, as this year saw the highest level of scepticism by the European public towards GM food during the 1990s, especially in the UK (Gaskell et al., 2004). Another reason to use UK data is the significant media attention that GM food has received during this period (Vilella & Costa-Font, 2004). Our findings suggest that learning about GM food risks and benefits takes place simultaneously so that the learning determinants are affected by different information sources, which in turn, are dependent on the empirical specification of the Bayesian learning process.

In the next section we outline individuals' learning processes with regard to GM food risk and benefit perceptions. Section 3 describes the data and the empirical model. Section 4 deals with the results and Section 5 concludes.

2. Individuals' learning processes regarding GM food risk and benefit perceptions

2.1. The risk–benefit perception dependence hypothesis

It is apparent from the findings of Gaskell et al. (2004) that public scepticism over GM food relies more on the perceived limited benefits rather than any appreciable risks connected with the specific technology under consideration. Yet, it is still intriguing that although individuals perceive some benefits from GM food these are less intense than the perceived risks. Even more intriguing is some qualitative (focus-group based) research indicating that the public does not necessarily differentiate between benefits and risks when it comes to applications that are relatively unknown, such as biotechnology in general (Bredahl, 2001). Therefore, it seems reasonable to deduce that (high/low) risk perceptions might not be separable from the (low/high) perceived benefits of certain technologies even though, to date, no quantitative study has dealt with the issue in the area of GM technologies. On the other hand, the novelty of both actual and potential commercialisation of biotech applications casts doubts on people's capacity to reason on the basis of a traditional risk–benefit model.[2] Finally, a potential bias in individuals' perceptions is the influence of loss aversion (Thahler, 1980), whereby individuals are systematically more sensitive to information signals conveying risks rather than benefits. Thus, when empirically examining attitudes, a separate estimation of risk and benefit perceptions might dismiss the fact that some individuals place different weights on risks and benefits.

Some studies highlight that risks and benefits are positively correlated as a result of the influence of affective responses underpinning risk judgements (Slovic, Kraus, Lappe, & Major, 1991) whereby it is argued that 'affect heuristics' can become a cognitive determinant of risk and benefit perceptions (Slovic, Finucane, Peter, & MacGregor, 2004). Furthermore, Finucane, Alhakami, Slovic, and Johnson (2000) argues that risks and benefits tend to be positively correlated by arguing that activities that are high in benefit are less likely to be high in risk and vice versa. However, we are not aware of any previous empirical study that models risk and benefit perceptions to take into account the possible correlation of the error terms of the risk learning determinants. In the area of GM food, this would result from the fact that some food-related risks are involuntarily taken by the individual, or individual perceptions of risk are systematically biased towards the

[2] Attitudes towards biotechnology applications, and especially GM food, exhibit some ambivalence resulting mainly from the contradictory nature of information conveyed from different sources (Costa-Font & Mossialos, 2005, in press; Gaskell et al., 1997; Hallman, Adelaja, Schilling, & Lang, 2002).

presence of significant benefits (e.g., mobile phones). Furthermore, individuals normally have insufficient knowledge of biotechnology developments; therefore, some ambiguity emerges within the information channels at their disposal, as there is insufficient knowledge to ground the learning process. Again, if individuals receive both positive and negative information signals on the risks and benefits of biotechnology, we should then expect that the two would not be perceived independently.

2.2. Risk perceptions under imperfect information

Exposure to personal risk is recognized as a normal aspect of everyday life. We accept a certain level of risk in our lives as necessary to achieve certain benefits. The controlling factor appears to be in the individual's ability to manage the risk-creating situation. However, the management of an individual's risks implies handling sufficient information to form subjective probabilities. Yet, in the case of GM food risks, existing information does not allow individuals to form objective risk estimates. Thus, risk perceptions are the result of perceptions of uncertain damage; that is, substantively they are a 'perception of uncertainty' rather than a perception of risk in Knightian terminology (Knight, 1921). Therefore, quantitative estimates of risk perceptions in probability terms might be meaningless in the context of a lack of a single scientific (or objective) probability estimate. Thus, some qualitative scale should be employed instead (Finucane et al., 2000; Slovic, 1987).

Given that risk learning cannot be complete, individuals might suffer from well-known biases, such as the overestimation of highly publicized and low probability risks (Fischhoff, Slovic, & Lichtenstein (1978)), and more specifically, individuals may suffer from media risk amplification. (Jenkins-Smith & Silva, 1998).[3] On the other hand, the degree of disagreement amongst information sources, as a cause of ambiguity, might be an important determinant of risk perceptions. Indeed, ambiguity might lead individuals to develop the perception that technology is not under their control, thus leading to a social amplification of risk (Jenkins-Smith & Silva, 1998). Both the existence of risk conflicts and the lack of properly quantified risk estimation may lead to imprecise risk information, a condition that may result in irrational responses to risk because individuals are ambiguity-adverse (Camerer & Weber, 1992). The consequences of ambiguity may be driven by the expected loss associated with an alternative course of action; that is, there may be a "fear effect".

Furthermore, due to the complexity of the uncertain choice situation surrounding biotechnology applications, trust emerges as a key variable that is often seen to reduce the complexity of decision-making under uncertainty (Viclund, 2003).[4] Therefore, in processing information, agents engage in a reasoned process of distinguishing between trustworthy and less trustworthy information sources. Moreover, risk perceptions can be strongly influenced by emotional appeals (Wyse & Krivi, 1987), environmental concerns, and beliefs about social and economic effects (such as strong ethical considerations) that might be amplified by the existence of ambiguity within information channels. Finally, the learning process associated with biotech risks may be defined by the nature of the information available. Scientific information is technical—it does not provide clues to the public about the status of scientific research to quantify risks to health or to the environment.

2.3. The rational learning model

The risk learning process is represented here through a Bayesian learning model (Viscusi, 1992). Accordingly, we assume that biotechnology risk and benefit information is constrained by the existence of multiple information channels from which we can distinguish public from private organizations. Moreover, assume that there are two scenarios. In the first situation individuals consume GM food where there is a π probability of a potential quantified loss (L), which leads to the following expected utility $(\pi)U(q,x-L)+(1-\pi)U(q,x)$ where q is the level of GM food consumption. In the second situation, individuals do not consume GM food $U(x)$. Yet, in a Bayesian learning model the formation of subjective beliefs, according to the different types of public and private information that individuals face, is joined with prior beliefs. Due to likely information biases in the real world, individuals mentally form a subjective probability on the likely effects of GM food. Let us assume that individuals display a baseline belief (ρ_0) that is updated according to private and public information, then the critical probability that determines consumption is given by

$$\pi^* = \frac{U(q,x)-U(x)}{U(q,x)-U(q,x-L)} \qquad (1)$$

That is, π^* is the risk that leaves individuals indifferent between consuming or not consuming GM food. Now, if $\pi \geqslant \pi^*$ then individuals would not consume GM food and vice versa. Furthermore, π^* indicates an evaluative measure that on the numerator includes the perceived utility or benefit and on the denominator, the perceived disutility of consuming GM food. Yet, given that in a world of imperfect information π might be based on a variety of information sources, including prior individual beliefs, it

[3] Some authors argue that given that the media compete for the provision of information, competitive pressures lead to the exaggeration of information containing risks (so called "risk ratchet") (Jenkins-Smith & Silva, 1998).

[4] Different cultures and political patterns might produce different levels of citizens' trust in various institutions, displaying evidence of 'trusts gaps' (Horning Priest, Bonafadelli, & Risanen, 2003).

is worth examining the process of information updating, which we conventionally assume follows a Bayesian model.

According to the Bayesian learning model, individuals will weight different information sources with weights determining the informational content of each source. We denote by (η) the weight of baseline beliefs and assume that individuals adapt their responses to new information. Thus, the latest information on the true probability of a GM food risk is ρ_1 weighted by ϑ denoting the informational content weight; and we can denote the resulting perception to be a risky event as follows:

$$\pi = \frac{\eta\rho_0}{\eta + \vartheta} + \frac{\vartheta\rho_1}{\eta + \vartheta} \quad (2)$$

and differentiating with respect to ϑ we obtain

$$\frac{\partial\pi}{\partial\vartheta} = \frac{\eta(\rho_1 - \rho_0)}{(\eta + \vartheta)^2} \quad (3)$$

which indicates that if the new information conveys higher objective risk information ($\rho_1 > \rho_0$) or the information conveyed is more credible (ϑ), this will lead to higher risk perception. Following this rationale, one might distinguish between different information sources and expand the model by distinguishing between public and private information sources as we report in Appendix A.

2.4. Extension and remarks

Now, let us turn to Eq. (1) where the critical risk is determined by the utility increase resulting from consuming GM food and the utility loss resulting from potential damage. According to this model, perceptions of benefit (e.g., usefulness of GM food) might not be independent or endogenously determine the perception of risk. Furthermore, if risks are understood as a probability of damage to an individual and/or to society, it also should be argued that benefits would result from similar information adjustment mechanisms—and thus would be affected by similar information determinants. The initial benefits of a specific technology will be perceived as a result of an estimate of a potential utility increase adjusted by those characteristics that give rise to benefits perceived by the population. Therefore, risk perceptions should be significantly corrected by benefit perceptions. Some scholars have identified evidence that the perception that GM food has no benefits will have a large impact on the public's attitude to it (Zepeda, Douthitt, & You, 2003). Gaskell et al. (2004) argue that the reasons for biotechnology scepticism lie in the lack of attractiveness of these products, which confirm a rule indicating that if products are, overall, attractive they appear to be less risky and vice versa. Studies acknowledge that individuals' risk perceptions are a function of factors other than the probability of harm—which is consistent with the view that risk and benefit perceptions are all dependent on common determinants (Slovic, Fischhoff, & Lichtenetain, 1979). Finally, risk, concern and trust were shown to be correlated with subjective attitudes, lending some support to the idea that perceived risk is only partly an expression of negative affects (Sjöberg, 1998).

3. Data, variable selection and the empirical model

3.1. The data

The data used in the study has been obtained from the *Eurobarometer 52.1* survey on science and technology conducted in 1999. Although the survey has caveats, to our knowledge it is the only EU survey available that meets our research needs. Principally, the caveats refer to the sampling procedure and the difficulties associated with measuring income and education among EU member states. The survey was conducted on a multi-stage random sampling basis rather than through pure random sampling. We have selected one country (United Kingdom) instead of performing a pooled analysis with fixed effects. Furthermore, although the survey contains subjective information on education and income, low associations between income/education thresholds and national data cast some doubt on the 'meaningfulness' of aggregating those thresholds in a single sample. Therefore, we do not use income data and rely exclusively on education along with variables that proxy income such as house size and pension receipt to proxy socio-economic status. The data is not gender biased and individual responses demonstrated a reasonable level of cooperation with the interviewers. Forty percent of the respondents were male, the remainder female. In each country, questions were put to a 'representative sample' of the national population over 15 years of age. In all, 16,082 people were surveyed in the European Union (EU-15), some 1300 in the United Kingdom (1000 in Great Britain and 300 in Northern Ireland). However, after listwise deletion of all missing cases the sample consisted of 1295 UK respondents. The study examines GM food described as the use of modern biotechnology in the production of food.

3.2. Variable selection

Risk and benefit perceptions were estimated without information of probabilities but derived exclusively by using qualitative perception estimates. The question was the following:

Question: 'To what extent do you agree, disagree that GM food is risky/useful for society?'

Attitudes were measured using an order scale whereby individuals were asked to indicate if they agree with a statement about whether a specific application should be encouraged. Responses followed an order that ranged from 'strongly agree to strongly disagree'. Table 1 provides the definition, the basic statistics and the expected effects of each of the variables employed in the model. However, unlike prior health related studies such as Viscusi (1990), GM food risks cannot be translated into a single number, especially in probability terms. Indeed, some difficulties

Table 1
Variable definition

Variable	Definition	Measurement	Mean [s.e.]
Dependent variables			
Risk	Perceptions of risk	Scale [+2, −2]	−0.456 [0.034]
Benefit	Perceptions of benefit	Scale [+2, −2]	−0.052 [0.035]
Explanatory variables			
Knowledge	Response to 12 questions on science	Numerical	6.274 [0.069]
Age	Age in years	Numerical	43.172 [0.456]
Religious	Self-definition as religious	Dummy	4.314 [0.049]
Gender	Male	Dummy	0.459 [0.014]
Cooperation	Interviewer's rate of respondents' cooperation on a 1–4 scale	Numerical	2.341 [0.024]
Rightist	Political identification as right wing	Dummy	0.069 [0.070]
Discuss	Respondent has ever discussed GM food	Dummy	0.603 [0.014]
Head	Respondent is a family head	Dummy	0.581 [0.014]
Trust_CO	Consumer organizations are the most trusted	Dummy	0.172 [0.010]
Trust_EO	Environmental organizations are the most trusted	Dummy	0.160 [0.010]
Awareness	Respondent is aware of GM food	Dummy	0.782 [0.012]

might arise as to whether this comparison can be made. Firstly, perceptions might be influenced by an individual's abilities to transform risks into probabilities. Secondly, individuals might not think in terms of probabilities, i.e. they might not follow the expected utility framework that the theory assumes. Thirdly, it might well be that individuals have a 'qualitative', unreasoned perception of risks that is modified by information that does not usually provide quantitative facts. Indeed, information is primarily of a qualitative nature, and thus, we should expert information to produce a marked tendency towards 'dread' of biotechnology rather than emphasizing its benefits.

In examining the determinants of risk perceptions, one might well distinguish private information channels (such as personal experience, knowledge, inputs from religious groups, and information derived through discussion with other people) from public information sources (e.g., environmental and consumer organizations, although mostly conveyed by the media, as well as government sources). Other relevant determinants that approximate information channels are gender and age. This is explained by the fact that information processing is age-dependent given the prevalence of certain values at different times, and the effects of previous experience on cognition of potential risks. On the other hand, several studies identify gender as an important element in shaping risk attitudes (Dwyer, Gilkeson, & List, 2002; Slovic, 1987). Being the households' head is found to be associated with awareness of food-related risks (Dosman, Adamowicz, & Hrudey, 2001). In our empirical specification we have included 'family head' as a variable to measure whether individuals that are responsible for others are likely to perceive risks in the same way. Finally, we have included as a control variable whether respondents have ever 'discussed' issues related to GM food.

We should expect to find significant age differences to explain patterns in the information mix available to people. Perceptions of biotech risks are largely influenced by the fact that these technologies are new and novel. Age influences the capacity to acquire new information, as it tends to shape prior experience as well as access to new information at school or university. If risk perceptions are formed over time—and there is a 'cumulative' conception of risk—we should expect individuals' age to display an effect in the risk-learning process. Furthermore, younger people's perceptions might be based on information disseminated by new media sources. On the other hand, given that education attainment increases with time, younger cohorts might be more prone to distinguish between potential risks rather than real risks. Unlike younger cohorts, older people have less access to new technologies and thus are expected to show a higher dread of biotechnology in response to a specific lack of knowledge. The influence of age might have to do with the fact that risk information might be generally derived from a person's own experience; consequently, we would also expect the weight given to this information to be small regardless of the probability of harm or benefit that it conveys. This prior 'experience' may come from a person's own professional background or information received from advocates within particular professions, and in a more limited way may be obtained from the degree of an individual's awareness of new risks. Finally, prior risk information might be approximated by religious beliefs over the use of biotechnology.

Ambiguity implies that individuals perceive risks with some degree of uncertainty due to a lack of sufficient knowledge of the possible damage that may result. Knowledge provides an idea of whether the learning process about the risks and benefits of GM food can be hindered by a lack of information. Precise probabilities on the occurrence of certain risks are ignored by the population and even by experts. Therefore, because knowledge is what distinguishes ambiguity from a risk assessment (Epstein & Zhang, 2001), in our equation we include knowledge as a variable. The 'knowledge' variable was estimated by computing the scores registered for a number of questions on life sciences. Specifically, the variable was measured by auditing a set of 12 binary-choice questions[5] about science applied to biotechnology. Each correct answer was given a value of 1 and each incorrect answer a value of 0. A value of 0 would imply complete ignorance, and conversely a value of 12 would refer to complete knowledge. The mean value of knowledge was 6.29 for the whole sample. This result suggests that individuals have a fair level of scientific knowledge, although it is far from complete.

In addition, our sample contains qualitative information on risk perceptions. Individuals were asked whether they (strongly) agree or (strongly) disagree with propositions about the risks of GM food. Among the answers individuals could respond 'Don't Know' (DK) which is likely to be endogenous, and capture the effect of uncertainty in individuals' information on GM food. We interpret 'don't know' (DK) answers to mean that individuals are unsure about the effects of GM food.

Finally, given the existence of some ambiguity in the information channel, risk information will be especially influenced by the information sources that people trust, particularly those they trust the most. We may define an individual's learning process according to the channels that convey information on risks, and essentially we may distinguish two main characteristics. Firstly, the population's previous experience of these products is quite small and as noted above, knowledge tends to be scarce. Therefore, we may expect either that prior beliefs do not largely influence risk perceptions or that they lead to large errors in the assessment of risks. Belonging to specific religious or political groups may play a role in determining previous beliefs about the risks associated with biotechnology. The role of these variables may be diverse. Firstly, they might capture the effect of some social reference group (e.g., being a member of some extreme political or religious community). Secondly, political values may lead to the support of extreme attitudes and they might interact with other variables relating to knowledge. Finally, we include information on individuals' trust in environmental groups, which are especially active lobbies against GM food, and consumer organizations, which provide information to advise consumer decision-making.

Moreover, the informational content of different information channels is often contradictory, and may hide underlying economic interests (e.g., the search for business opportunities under conditions of market power). On the other hand, information is updated differently depending on whether individuals have some specific interest in the area, and thus are aware of such risks. Therefore, the accuracy of new information is expected to increase with individuals' awareness of the GM food debate. However, a different effect might be expected if technology related information is characterised by some ambiguity in the way it is communicated and perceived (Costa-Font & Mossialos, 2005).

3.3. The empirical model

As we hypothesize in Section 2, risk and benefit perceptions are likely to be associated so that they are best seen as endogenous. If this is the case, two-stage least squares (2SLS) models should be employed, which require the use of certain variables as statistical instruments of benefit perceptions.[6] This will take into account that there might be some correlation between an explanatory variable such as benefits perceptions and the error terms of the regression model as long as it is possible to identify some valid instruments. However, even when 2SLS are adopted, the errors in different equations may be correlated. This might be due to the specific source of association between risks and benefits. If risks and benefits are an expression of a similar unobserved variable (so-called 'unobserved heterogeneity') this will be captured by the correlation of the error terms of risks and benefits perceptions. In this case the efficiency of the estimation may be improved by taking these cross-equation correlations into account. According to Davidson and MacKinnon (1993) a method to overcome such effects is to use three-stage least squares (3SLS) which generalizes the two-stage least-squares method to take account of the correlations between equations; 3SLS is generally consistent and more efficient than 2SLS asymptotically, and at least as efficient as any other estimator which uses the same amount of information. The covariances of the error terms are then estimated from the 2SLS residuals. The following is the basic 3SLS specification where we parameterize the perceptions of risks and benefits as follows:

$$\text{BENEFITS}_i = \beta_{10} + \beta_{11}X_i + \varepsilon_i \tag{4}$$

$$\text{RISKS}_i = \beta_{20} + \beta_{21}\text{BENEFITS}_i + \beta_{22}Z_i + \mu_i \tag{5}$$

The variables X, Z refer to the covariates defined in Table 1 following the previous section's discussion. From Eqs. (4) and (5), it is evident that the system of equations is statistically identified and follows a recursive approach.

[5] There were 12 questions and respondents had to answer whether they thought the statement was true or false. The questions were (1) there are bacteria that live in waste water, (2) ordinary tomatoes do not contain genes while GM tomatoes do, (3) the cloning of living things produces exactly identical offspring, (4) by eating a GM fruit the person's genes could also become modified, (5) it is the father's genes that determine whether the child is a girl, (6) yeast from living beer consists of living organisms, (7) it is impossible to find out in the first few months of pregnancy whether the child will have (Downs syndrome, trisonomy or mongolisms), (8) GM animals are always bigger than ordinary ones, (9) more than half of humans' genes are identical to those of chimpanzees, (10) it is impossible to transfer animal genes into plants, (11) criminal tendencies are genetically inherited and (12) musical abilities are mainly learned.

[6] Two-stage least squares regression (2SLS) is a method of extending regression to cover models which violate ordinary least squares (OLS) regression's assumption of exogeneity so that the disturbance term of the dependent variable is correlated with the cause(s) of the independent variable(s).

More specifically, the variable for knowledge and trust in environmental organization is employed to explain benefits but not risk perceptions.

4. Results

4.1. Empirical evidence

Inspecting Table 1 we find that both risk and benefit perceptions display a negative sign, which indicates that the majority of respondents perceive small benefits and remarkable risks compared to the benefits associated with GM food. The UK survey score indicating the individual's 'knowledge of science' averaged at 6.3 out of 12, which indicates a fair degree of literacy, and the mean age of the sample was 43 years. In a self-reported religiosity scale, the average level was 4.3 out of 10 indicating that in terms of being religious people see themselves, on average, as being at the low–medium to low level. Only 7% of people in the sample defined themselves politically as being right-wing, 60% have discussed GM food issues at one time or other, and about 17% trust consumer and environmental organizations. Finally, in our empirical analysis we include, as a control variable, the extent to which respondents cooperated with the interviewer. A fair level of cooperation with the interviewers was recorded for the survey, with a score of 2.3 out of 4.

Table 2 highlights that about 30% did not respond to the question on the risks and benefits of GM food. Non-responses might take place due to a variety of reasons, relating to probable ambivalence in the process of information acquisition, which translates into ambivalent attitudes. Another possible explanation for individuals' non-response is due to 'rational ignorance' (Costa-Font & Mossialos, 2005, in press). That is, information about the risks and benefits of GM food is costly to acquire; thus, given this feature, it is rational not to seek out information and thus not to report a specific answer. However, looking at the data in Table 2 one should bear in mind that the issue of GM food in the UK reached its peak in 1999 in terms of risks perceptions and the intensity of media reporting (Villella & Costa-Font, 2004). Furthermore, the majority that do report an answer tend to report weak judgments, such as ''tend to'' rather than strong judgments in the form of ''strongly agree or disagree'' indicating that it is likely that attitudes are significantly information-dependent.

Table 2
Distribution of benefits, risks and moral acceptability of GM food in the UK (1999)

	Number	%	Cummulative %
Useful			
DK	395	30.50	30.5
Strongly agree	188	14.52	45.02
Tend to agree	227	17.53	62.55
Tend to disagree	299	23.09	85.64
Strongly disagree	186	14.36	100
Risky			
DK	373	28.80	28.80
Strongly agree	91	7.03	35.83
Tend to agree	189	14.59	50.42
Tend to disagree	322	24.86	75.29
Strongly disagree	320	24.71	100

Question: To what extent do you agree–disagree that genetically modified (GM) food is risky/useful for society?

Table 3 provides the results of the models. The first column reports risk perceptions using OLS. Interestingly, a higher benefit perception places a negative effect on risk perceptions. This would indicate that benefits and risks might be two sides of the same coin, whereby high risks imply small benefits and vice versa. Risk perceptions rely on the role of awareness—which might proxy the role of the media and, in general, public information about risks, and reflect the fact that individuals trust environmental and consumer organizations. Because benefits and risks perceptions are rather endogenous, we undertook a Hausman test, which indicated that at the 1% level we reject the null hypothesis of exogeneity.

We proceeded by estimating a 2SLS model where 'knowledge' and 'trust of environmental organizations' were taken as observation variables to instrument benefit perceptions in the first stage. These variables are good instruments given that they were not correlated with benefits perceptions. Interestingly, the negative effect of benefit perception triples once the model is corrected for endogeneity. The effect of individual awareness stays the same but now the role of political ideology comes into effect. Having conservative political tendencies increases the perception of risks while the effect of trusting consumer organizations does not significantly vary with the empirical specification and is statistically significant. However, religiosity did not emerge as a significant predictor. On the other hand, benefit perceptions are negatively associated with knowledge of science—which measures formal knowledge—and are statistically significant, which indicates the role played by information costs; that is, in order to perceive the benefits of GM food one needs a prior investment in GM information. Another important result is that the intercept is never significant, which in the context of a Bayesian learning model measures the effect of prior information. Interestingly, and possibly given to the novelty of GM food, the constant term is not significant. This result is consistent with the novelty of the commercialisation of GM food. Finally, female gender is systematically associated with higher risks and lesser benefits, which is consistent with previous literature.

As mentioned above, given that the perceptions of risks and benefits are formed at the same time, one might expect some correlation in the error terms of both equations in addition to the endogeneity of benefit perceptions in the risk perceptions equation. Thus, we estimate a 3SLS, which accounts for this feature. If the hypothesis of no correlation were rejected, then we would find no differences between the 3SLS and 2SLS models. However, as we see in the two final columns of Table 3, there is a significant differ-

Table 3
Risk and benefit perceptions determinants [standard errors in brackets]

	Risk (OLS)	Risk (2SLS)	Benefit (2SLS)	Risk (3SLS)	Benefit (3SLS)
Benefit	−0.119** [0.035]	−0.337** [0.065]		−0.296** [0.087]	
Knowledge	−0.010 [0.019]		−0.031* [0.017]		−0.030* [0.015]
Awareness	0.407** [0.095]	0.436** [0.097]	0.134 [0.085]	0.420** [0.096]	−0.046 [0.096]
Age	0.003 [0.003]	0.004 [0.003]	0.005* [0.002]	0.001 [0.003]	0.009** [0.003]
Religious	0.010 [0.022]	0.012 [0.023]	0.009 [0.020]	0.011 [0.023]	0.003 [0.023]
Gender	0.133 [0.085]	0.095 [0.088]	−0.174* [0.077]	0.189* [0.086]	−0.280** [0.086]
Cooperation	−0.056 [0.050]	−0.058 [0.051]	−0.009 [0.045]	−0.055 [0.050]	−0.007 [0.050]
Rightist	0.236 [0.152]	0.322* [0.156]	0.396** [0.136]	0.198 [0.153]	0.369* [0.154]
Discuss	−0.008 [0.083]	−0.014 [0.085]	−0.024 [0.075]	−0.004 [0.084]	−0.028 [0.084]
Head	−0.123 [0.089]	−0.111 [0.090]	0.055 [0.080]	−0.114 [0.090]	0.009 [0.090]
Trust_CO	0.211* [0.103]	0.197* [0.091]	0.066 [0.093]	0.224* [0.105]	0.079 [0.105]
Trust_EO	0.342** [0.105]		−0.148 [0.094]		−0.326* [0.106]
Intercept	−0.053 [0.249]	−0.071 [0.253]	−0.081 [0.223]	−0.045 [0.252]	−0.076 [0.252]
R^2	0.080	0.060	0.10	0.070	0.065
F-Test	7.030	6.440	30.23		
χ^2				51.09	45.56
Observations	1053	1053.0	1053	1053	1053.0

* Significance at 5%.
** Significance at 1%.

ence in the coefficients when a 3SLS is estimated. The effect of benefit perceptions smoothes out slightly while the 'do not trust environmental organizations' attitude turns out to be negatively associated with benefit perceptions. The effect of gender stands out as the most significant, resulting from taking into account the correlation between the error terms. The result consistently identifies that women systematically perceive higher risks and lesser benefits to GM food. Interestingly, in these circumstances, the effect of age becomes significantly associated with larger benefit perceptions. Finally, trust in environmental organizations (but not in consumer organizations) becomes a significant determinant of benefit perceptions when using 3SLS.

4.2. Limitations

We have not been able to investigate the specific weight that individuals attach to information on risks compared to that on benefits. Moreover, the paper has some caveats, as the study refers to a single country and one might argue that individual responses are country-specific. On the other hand, several relevant variables were not included due to the limited disposal of information such as the specific effect of the media. Finally, individuals' estimates of risk perceptions might depend on previous experience that would be expected to determine the existence of a prior estimate of a risk and benefit perception. However, this information was only measured through the effect of the constant term in the regression model.

5. Discussion

Although some previous research has suggested that risk and benefit perceptions might be the representation of the same feature, limited research has been undertaken to test this hypothesis. This paper has reported evidence indicating that the perceptions of risks and benefits of GM food are not independently distributed and should be modelled jointly. The paper draws upon the use of econometric techniques, namely 2SLS and 3SLS to account for the existence of simultaneity and endogeneity of risk and benefit perceptions in the way that a recursive econometric system such as a 2SLS or a 3SLS allows for testing of statistical linkages between the explanatory variables. Evidence suggests that both risks and benefits are simultaneously determined and explained by similar risk learning factors. Therefore, those individuals that are likely to identify high risks with regard to GM food might be those who also identify lower benefits. This evidence is consistent with the idea that risk perceptions are the results of both a perception of a potential disutility as well as a lack of benefits from some new technologies such as the 'current generation of GM food' which does not yet provide sizeable benefits for the public. Furthermore, our results are consistent with previous evidence that suggests that European 'public opinion' on the risks and benefits of GM food is fragmented and subject to significant ambivalence, with ambivalence referring to a simultaneous endorsement of risk and benefit perceptions (Pidgeon et al., 2005).

Moreover, we have identified some personal characteristics that are associated with differences in the perceptions of risks and benefits of GM food in the UK. Here, the paper's contribution has been to identify the specific GM food risk-learning determinants once accounting for potential endogeneity and simultaneity issues. Our empirical estimates indicate that prior beliefs do not seem to be influential in determining perceptions of the risks and benefits of GM food. Both perceived risks and benefits of GM are not high and 30% of the sample does not report a definite perception. However, our empirical evidence indicates the importance of public and private information sources. In particular, knowledge of science significantly affects perceptions of benefits, whereby the larger the individual knowledge of biotech-related facts generally, the larger the perceived benefits of GM food. This points out that there might be a 'fear of the unknown' underlying individual perceptions of GM food, especially resulting from a failure of different stakeholders to provide a clear view of what the public can gain or lose from the extension of GM food. The potential impact of advertisement and communication campaigns to influence risk perceptions is captured through the effect of individuals' awareness of GM food, which appears as a relevant finding that is consistent with prior studies (Gaskell et al., 2004). On the other hand, we find that gender-specific effects remain once the endogeneity and recursiveness of benefit and risk perceptions is controlled for. However, the effect of age is only significant as a determinant of the perceived benefits of GM food rather than its risks. This result is consistent with the idea that information channels exert a generational dependent effect, whereby younger cohorts communication updates rely more heavily on risk rather than benefit information on GM foods.

Altogether, our study indicates that communication policies combined with the effect of private information sources most likely have affected individuals' judgements regarding the benefits and risks of GM food. Unlike other known risks such as smoking (Viscusi, 1992), individuals' prior assessments of risks and benefits are not likely to bias perceptions of GM food. Moreover, although individuals might distinguish between benefits and risks in forming their perceptions, this study reveals that information on GM food that leads to a perception of risk is likely to be mentally processed as a negative benefit, and vice versa.

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Appendix A

Let us distinguish the latest estimation of the true probability depending on the informational source as ρ_{11} if the source comes from public information channels and ρ_{12} if the source comes from private sources such as person's own experience. As before, the informational content parameter can be expressed as ϑ_{11}, ϑ_{12} depending on whether the information source represents a public or a private source of information. Under these assumptions we can re-write (2) as

$$\pi = \frac{\eta\rho_0}{\eta + \vartheta_{11} + \vartheta_{12}} + \frac{\vartheta_{11}\rho_{11}}{\eta + \vartheta_{11} + \vartheta_{12}} + \frac{\vartheta_{12}\rho_{12}}{\eta + \vartheta_{11} + \vartheta_{12}} \tag{A.1}$$

Accordingly, we can determine the effect of an increase in the publicly provided information as

$$\frac{\partial\pi}{\partial\vartheta_{11}} = \frac{\eta(\rho_{11} - \rho_0) + \vartheta_{12}(\rho_{11} - \rho_{12})}{(\eta + \vartheta_{11} + \vartheta_{12})^2} \tag{A.2}$$

and the effect of an increase in private information as

$$\frac{\partial\pi}{\partial\vartheta_{12}} = \frac{\eta(\rho_{12} - \rho_0) + \vartheta_{11}(\rho_{12} - \rho_{11})}{(\eta + \vartheta_{11} + \vartheta_{12})^2} \tag{A.3}$$

Again, if the informational content of public/private information increases, then the individual's risk perception will rise depending on the weight of public information with respect to private information in the process of risk perception formation.

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