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Katarzyna Zagórska
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Nick Hanley

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"GMO – Doesn't Have To Go!" – Consumers' Preferences Towards Genetically Modified Products Labelling and Sale

Katarzyna Zagórska[1], Mikołaj Czajkowski[1], Nick Hanley[2]

[1]*University of Warsaw, Faculty of Economic Sciences*
[2]*University of Glasgow, Institute Of Biodiversity, Animal Health & Comparative Medicine*
** Corresponding authors: mc@uw.edu.pl, kzagorska@wne.uw.edu.pl*

Abstract: We investigated public preferences regarding labelling and sale of genetically modified (GM) products in Poland. A Discrete Choice Experiment (DCE) was used to investigate public preferences and Willingness To Pay (WTP) for new policies changing the current regulations with respect four types of products: food, processed food, commercial products, and pharmaceuticals. In addition to reporting the general results, we analyze the social and behavioral drivers of consumers' preferences and WTP. The study examines relationship of self-assessed and objective knowledge, perceptions of risks and benefits, and attitudes associated with GMO to consumers' preferences.

Keywords: genetically modified organisms, labelling preferences, GM marketing, consumer preferences, GMO knowledge

JEL codes: Q18, Q50, D12, D91

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Author contributions: MC and KZ devised the paper's central idea together and designed the study. KZ developed the predictions, wrote introduction, literature review; she described study design and results in original manuscript. MC proposed econometric approach, wrote about the method, and performed the econometric analyses. All authors contributed to conclusion and the final manuscript.

1. Introduction

Tim O'Reilly identifies genetic engineering as one of the technology trends that gradually progress to suddenly change the world we live in (O'Reilly, 2019). In a rapidly changing climate, by 2050 both more productive and more resilient crops will be a necessity to feed the world's 10 billion population (Searchinger et al., 2019; Shanker, 2019). Genetic engineering is an important driver of innovation and a scientific response to conditions requiring urgent adaptation, such as changing environmental and climate conditions, or health perils related to poverty.

Genetic modifications (GM) remain a controversial topic of a heated public debate, because of unpredictable consequences and potential costs, that might or might not outweigh their benefits. GM products, especially foods, are subject to safety assessment (WHO, 2014). Nevertheless, public opinion remains negative towards genetically modified organisms (GMO), especially GM foods (George Gaskell, Bauer, Durant, & Allum, 1999; Scott, Inbar, & Rozin, 2016). Accordingly, the EU regulations require consumers be informed on the GMO contents of such products (European Commission, 2022).

Consumers bear all potential costs of market regulations with regard to GM products, regardless of whether market is insufficiently or over-regulated. Real market examples of consumers paying for insufficient regulation include 'non-GMO' salt (which by substance cannot be GM) sold with a mark-up, or numerous illegal gene-engineered orange flowering petunias accidentally discovered in a public place to later get destroyed (Haselmair-Gosch et al., 2018; Malakoff, 2017).

On the other site, overregulation and precautionary principles stifle approval of important innovation. For example, withholding vitamin A enhanced GM Golden Rice imposed health costs (blindness) in developing countries (example from McKie, 2019; Regis, 2019). The worst case scenarios include anti-science policy build on public opinion driven by biased perception of future risks (Bird,

2020), with unintended consequences such as increased mortality (Neidell, Uchida, & Veronesi, 2019). The dynamic nature of regulatory trade-offs in face of uncertainty makes benefit-cost analysis essential to design regulations (Thierer, 2019).

The goal of this study was to provide an insight into public preferences towards GMO labelling policy and market sale. We used a DCE to gauge consumers' preferences regarding regulations of GMO. We distinguish between preferences for food, processed food, pharmaceutical products, and commercial products. We carefully explained these categories to respondents and provided examples of potential GMO uses and presence. For each product category, four policies were considered that differ in the level of control over GMO presence on the market: a ban of such products, obligatory labelling, voluntary labelling, and labelling ban (no labels are allowed to differentiate between GMO and non-GMO products of the category, similarly to the USA law). We propose new, original choice experiment design to measure the policy preferences.

Our results offer new insights into factors that shape the complex decision-making process with regard to GMO, by controlling respondents' objective and subjective (self-assessed) level of knowledge, perceptions of health and environmental risks/benefits, and using various measures of risk aversion We want to understand which factors play persuasive role in shaping public opinion towards GM products. The interaction between these factors is important, as people's subjective perception of uncertain threats/benefits, on which they mostly rely decisions, is often biased compared to objective probabilities (Paek & Hove, 2017). Such biases can lead to decisions motivated by emotional responses, rather than by truthful preferences based on objective information.

The relation between consumers' knowledge and preferences for GMO products can potentially be extrapolated to how people perceive, learn and process information in the context of new technology and innovation developments. Understanding of product categories whose genetic

modifications are accepted on the market might help in creating regulations that support consumers' views and preferences, but also in introduction of new products that offer benefits favored by the general public.

2. Previous literature

GMO regulations

Legal frameworks for GM products' labelling vary globally (Loureiro & Hine, 2004) and within the European Union. These policies may reflect differences in public opinion across cultures and geographical regions (Chen & Li, 2007; Van Wezemael, Caputo, Nayga Jr, Chryssochoidis, & Verbeke, 2014). Previous studies suggest that while introducing mandatory labelling of GM products can reduce social welfare in the United States, it can be quite the opposite in the EU, where abolishing the obligation to label GM food products could reduce social welfare (Jayson L Lusk et al., 2005). This result depends on costs of introducing change in initial regulations, but also differences in social preferences and associated benefits of information provision to consumers.

The European Union's (EU) legal framework regulates conditions of the GMOs development, release, cultivations and placing on the market. Food produced from GMOs are subject to mandatory GM labelling requirements, in accordance with Articles 12 and 13 of Regulation (EC) No 1829/2003. GM food must have a label stating: "genetically modified" or "produced from genetically modified (name of the ingredient)". GM ingredient is subject to 0.9% threshold exempt, viewed as unintentional traces of GMOs in conventional products. Products such as meat, milk or eggs obtained from animals fed with genetically modified feed are not subject to the traceability requirements.

"GMO-free" label is not regulated at the EU level. Member states either formulate own standards, or manufacturers can rely on lack of regulations and freely use "GMO-free" label. In Poland, new system for GMO-free labelling entered into force on January 1, 2020. The labelling rules aim to

allowing consumers to make informed choices, but reduce the potential misleading impact of packaging and advertising. This type of voluntary information is created to claim unique product characteristics, that can in fact be shared by all products in a category.

General public preferences

The marketing potential of products labelled as "GMO" or "GMO-free" depends on consumers' preferences and real purchasing decisions. Research on consumer evaluation of GMO products usually relies on one of two approaches: (1) auctions of food products to evaluate price mark-ups, or willingness to pay for labeled products; (2) measurement of concepts such as 'acceptance', 'perceptions', 'attitudes', 'objection', 'concerns'. Generally, GM content information reduces intention to purchase a product and willingness to pay for it (Huffman, Rousu, Shogren, & Tegene, 2007; Huffman, Shogren, Rousu, & Tegene, 2003; Noussair, Robin, & Ruffieux, 2002; O'Fallon, Gursoy, & Swanger, 2007). The research of preferences for national labelling policy is rather limited (Hine & Loureiro, 2002), and very little research pertain to economic aspects of the GM products labelling.

For the purpose of literature review, we will assume that consumer attitudes or approval are closely related to economic measures of preferences intensity (Hess, Lagerkvist, Redekop, & Pakseresht, 2016; Kahneman, Ritov, Jacowitz, & Grant, 1993). Based on that, the literature highlights crucial importance of information, trust and knowledge of product, and process attributes for the formation of risks and benefit perceptions, and individual values and risk aversion (Caswell, 1998; Costa-Font, Gil, & Traill, 2008; McCluskey & Loureiro, 2003; Soregaroli, Boccaletti, & Moro, 2003) for evaluation of GMO. These dimensions might be related to socio-economic and demographic attributes.

People object more to GM food than to GMOs developed for other applications. Most studies concerns only foods, for example GM beef, salmon, vegetable oil (Chern, Rickertsen, Tsuboi, & Fu,

2003), rice (Jayson L. Lusk, 2003), bread (Wuepper, Wree, & Ardali, 2019) etc. Only a small fraction of literature compares attitudes towards different product categories.

Also Poles are afraid that GMO in food products might have a negative impact on the environment and human health and they have high expectations concerning the scope of regulatory framework and labeling of GMO products. 55% to 67% consider the use of biotechnology in food production to be harmful (Centrum Nauki Kopernik, 2012; Twardowski, 2008). The use of genetic engineering in medicine (56% to 58%) and for environmental protection (69%) is supported by the majority of Poles (Centrum Nauki Kopernik, 2012; Twardowski, 2008). Based on a literature review, we formulated the following hypotheses:

Hypothesis 1a: Consumers prefer GM food ban or mandatory labelling (status quo), compared to voluntary labelling.

Hypothesis 1b: Opposition to GM food is more explicit, than using GMO in other product categories.

Polish context

In Poland, the first GMO public opinion poll was conducted in 1998, with questions matching the Eurobarometer survey. Back then, 38% of Poles had not heard about genetic engineering, 2/3 were willing to buy GM products, and 80% insisted that GM content was labelled (Twardowski, 2007). In later Eurobarometer studies in 2005 and 2010, Poles confirmed limited knowledge about biotechnology, genetic engineering, and GMOs (George Gaskell et al., 2006; George Gaskell et al., 2010). Poles still know very little about GMOs. 48% of Poles have not encountered the term GMO; 3.3% of Poles are able to correctly develop the abbreviation GMO, 66% of Poles don't know what GMO is, and 75% know little or almost nothing about GMOs (Centrum Nauki Kopernik, 2012).

At the same time, Poles most often associate GMOs with plants and food production, in particular with GM corn (78%), soya (63%), and rape (55%) (Centrum Nauki Kopernik, 2012). Also, 23% say that cows can be genetically modified to produce butter enriched with omega-3 fatty acids. 70% of respondents do not know that bacteria are also genetically modified to produce insulin.

Distribution of attitudes

According to the conceptual framework proposed by Costa-Font et al. (2008), attitudes among consumers are in continuous change due to developing knowledge about biotechnology. They propose three main groups regarding attitudes toward GM food: (1) anti-GM food or pessimistic, (2) information searchers, (3) and GM-accepters or optimistic, with different compositions of such groups in a specific society. In countries with limited knowledge of GMO, such as Poland (Centrum Nauki Kopernik, 2012; Kapla & Robak, 2014; Twardowski, 2005, 2008, 2012), one would expect to find information searchers with very negative (positive) information conveyed with pessimistic (optimistic) attitudes.

Hypothesis 2: A group of negative information searchers – people with negative attitudes and low level of (objective and self-assessed) knowledge about GMOs – represent a majority.

Relation between knowledge, information and GMO acceptance

Knowledge and general attitudes are the core elements of the purchase intention model for GMO products (Verdurme & Viaene, 2003), but there is no scientific consensus regarding empirical relationship between knowledge and GMO evaluation. Part of the research claims that knowledge have positively influence on intention to buy GM products (Boccaletti & Moro, 2000; Hossain, Onyango, Schilling, & Hallman, 2003; Papastefanou, Springer, Tsioumanis, & Mattas, 2003; Soregaroli et al., 2003), other show the opposite (Ghasemi, Ahmadvand, Karami, & Karami, 2020; Hine & Loureiro, 2002; Huffman et al., 2007; McCluskey & Loureiro, 2003). The relationship between knowledge and

attitudes must not be causal, as attitudes and preferences plausibly affect consumers' interest (Wuepper et al., 2019). Therefore, the analyses of GM acceptance to knowledge have explanatory, rather that confirmatory character.

Knowledge is a multidimensional construct, which allow for parallel use of subjective and objective measures (House et al., 2004). Most of early studies used only one measure of knowledge – objective or subjective, which lead to inconclusive regarding the other, and not showing the full picture (Boccaletti & Moro, 2000; McCluskey & Loureiro, 2003).

On top of that, various measures of objective knowledge exist. The selection of final measurement tool is subject to a degree of arbitrariness. Quiz or tests results correlate positively with acceptance of GMO on the market and propensity to buy GM products (Hossain et al., 2003; Koivisto Hursti & Magnusson, 2003; Soregaroli et al., 2003). Same is true for professional knowledge, for example a as of subject of studies – biotechnology/ bio engineering, natural sciences (Saher, Lindeman, & Hursti, 2006), and scientific literacy (Fernbach, Light, Scott, Inbar, & Rozin, 2019). Awareness of the GM market (Loureiro & Hine, 2004), understanding of biotechnology and agriculture increases GM products acceptance (Blancke, Van Breusegem, De Jaeger, Braeckman, & Van Montagu). Less-educated consumers have higher preference for biotech labels (Harrison & Mclennon, 2004). On the contrary, agricultural knowledge and awareness of the benefits of the GM cultivation are associated with higher price sensitivity (James, Rickard, & Rossman, 2009; Wirth, Stanton, & Wiley, 2011). People with informed prior beliefs discount GM-labelled food products more highly than those who had uninformed prior beliefs, which might suggest that prior beliefs are rather negative (Huffman et al., 2007). Variety of survey and experimental designs shape research results, that in turn reduce generalizability of conclusions reached and possibilities of conceptual replication.

Subjective measures can be related to strong positive or negative attitudes. Baker and Burnham (2001) show that subjective assessment of knowledge about genetic modifications enhance intention to buy GM food, but according to Boccaletti and Moro (2000) it decreases willingness to pay for such products. McCluskey and Loureiro (2003) states that self-assessment of knowledge about biotechnology and higher level of education is related to higher discounts required to buy GM food.

Costa-Font et al. (2008) hypothesized that knowledge is singular human attribute that noticeably enhances the likelihood of GM food acceptance, especially when objective rather than perceived knowledge is examined. Consumers, who reveal either rejection or acceptance of GM food (strong attitudes), seem to be strongly influenced by individual values and hence by subjective knowledge. Fernbach et al. (2019) confirm this phenomena for GM food objection in America, France and Germany. They showed that GM food opponents had believed they were the most knowledgeable about this issue, yet scored the lowest on tests of scientific literacy. The pattern also holds for medical application of genetic engineering technology (gene therapy).

Hypothesis 3a: Self-assessed knowledge is a significant positive predictor of extreme GMO opponents and supporters.

Hypothesis 3b: Objective knowledge is a significant positive predictor of extreme GMO supporters.

Hypothesis 3c: For extreme opponents, knowing less (worse quiz results) is correlated with higher self-assessed knowledge.

Relation between risk-aversion and GMO acceptance

In relation to GMOs, risk is often measured with a question "how risky do you consider GM products to be", and not as individual risk aversion. High risk perception leads to strong preference for mandatory labelling (Harrison & Mclennon, 2004) and potential avoidance of GM products. GMO

perceived hugely through the prism of risk in the EU (Hess et al., 2016). At the level of individual attitudes, consumers who seek to avoid GM content are typically those relatively more risk conscious/oriented (Costa-Font et al., 2008). Baker and Burnham (2001) call the market segment „Safety seekers"; other groups are "National brand buyers" and "Price pickers".

Hypothesis 4a: Risk attitudes are significant predictors of GMO opponents.

Hypothesis 4b: Consumers concerned about GM food safety for health and environment prefer GMOs ban or obligatory labelling.

Hypothesis 4c: Consumers who buy quality and environmentally friendly products prefer GM food labelling.

3. Empirical study

3.1. Survey administration and sample descriptives

The study was conducted between March-June 2016 on the representative sample of 4,500 Polish adults. The study sample is representative with respect to the following characteristics of the general population of Poland: sex, age, education, population of the place of residence, region of residence. Computer-assisted web interviews (CAWI) were used. Data collection was coordinated by two leading market research companies – PBS and GfK. It elicited consumers' preferences towards GMO labelling policies with discrete choice experiment (DCE) technique.

3.2. Questionnaire design

The DCE is a stated preference, survey-based technique. Our survey had four standard main parts, i.e. introduction, warming-up questions, preference elicitation, and follow-up questions. It had many introductory and ending questions constructed to better understand the relation between consumers' knowledge, opinions, attitudes and preferences. In the study we also created three kinds of

experimental treatments to exert control over influence of knowledge, information and risk perceptions on preferences. Pre-testing of the survey included focus groups, individual interviews in the form of verbal protocols and in-depth cognitive interviews (Johnston et al., 2017; Schkade & Payne, 1994) and insights from sociologists and DCE practitioners. This helped understand respondents' interpretation of the questionnaire, pretest survey language and graphics and ensure clarity and comprehension. The survey in Polish and its full translation into English is presented in supplementary materials.[1]

Introduction and warming-up questions

In the introduction consumers were informed that the study is conducted by the University of Warsaw and that purpose of the questionnaire was gather data about public opinion regarding genetically modified organisms (GMO) and regulations of GMO's sales on the Polish market. Subjects were incentivized to reveal truthful preferences with information that the results would be presented to authorities, which can have impact on future regulations. Later in the survey, we reassured consequentiality with a reminder that each policy comes at a cost and an explanation on how change in GMO policy can influence household budget.

The second part was designed to learn more about respondents' habits, knowledge, and attitudes. We asked respondents if they were primary household shoppers and about factors influencing their purchasing decisions (how important they considered prices, quality, country of origin, and environmental friendly production processes when choosing a product). Then a definition of genetically modified organisms was displayed ("Genetically modified organism (GMO) is any

[1] The supplementary materials to this paper are available at http://czaj.org/research/supplementary-materials.

organism whose genetic material has been altered using genetic engineering techniques. GMO can be an animal, a plant or microorganism (bacteria, fungi).”). We found it important that the definition precede a set of questions regarding GMO, because earlier study conducted in Poland found that only 3.3% of Poles can correctly explain the abbreviation (Centrum Nauki Kopernik, 2012).

Knowledge measurement

A set of questions about subjective (self-assessment) and objective (quiz) knowledge about GMO was asked. First question was general question on subjective assessment of one’s knowledge: “How much do you think you know about GMOs?” with responses measured on a 7-point scale (“1 – I don’t know anything” to “7 – I know a lot”). Then, using same question, we asked more specifically about knowledge with regard to GMO’s health effects, environmental impacts, benefits, threats, and regulations. To measure objective level of knowledge, a true or false quiz was used. The quiz consisted of 15 statements, that referred to facts on regulations, health risks and benefits, environmental risks and benefits, and genetic basics. The quiz was designed to objectively measure subjects’ initial state of knowledge, so it directly preceded the section in which we provided even very basic information about GMO products. Full translation of the quiz can be found in Appendix 1.

Then we provide respondents with information needed for careful and well-informed decision making. We considered provision of objective information (as before referendum) crucial for quality of the results and preference formation, as most of the respondents said they had little or no prior knowledge of the topic. Four categories of products in which GMOs might be used: (1) food, (2) in food production, but final product will not contain any modified genes, (3) pharmaceuticals, (4) commercial products. These defined based on on-line resources, especially the consumer-oriented website www.gmo-compass.org funded within the European Commission’s Sixth Framework

Programme. Table 1 presents relevant descriptions of product categories, that also represent attributes of the discrete choice experiment.

Table 1. Descriptions of GMO products presented to respondents

Product category	Description
Food	GMO **food** include for example to cereals/grains, fruits, vegetables and food that consist, contain or are made from GMOs. Examples include: – plant resistant to certain pests, diseases, or environmental conditions; – spoil/rot less and slower, once harvested (increased shelf life) – resistant to certain chemical treatments (ex. herbicides) – have improved nutrient profile or contain less of hazardous/harmful substances
Processed food	GMO used **in food production**, not present in a final product, is not directly consumed by humans, but instead are processed in ways that remove DNA and its immediate products (proteins), so considered foods made 'with the help of GMOs'. Examples include: – genetically modified plants used in production of food that does not contain DNA, genes and its immediate products (proteins) after processing; plants used to derive DNA and protein free products; – plants used as fodder for animals (ex. milk from cows fed on fodder including GM plants) – microorganisms used in production of additives and food processing (ex. in cheese or juice production)
Pharmaceuticals	GMO used in **pharmaceutical production**, GMO used to produce proteins used as medicines, source of human therapeutics, for example: – microorganisms or plants used in production of medicines (hormones, vaccines, enzymes) – animals used as source of pharmaceutical ingredients (ex. milk from genetically modified goats)
Commercial products	GMO used in production of **commercial products**. Derived from GMO, which are not used for food and feed purposes, for example: – sources of industrial and commercial products - plants resistant to certain pests, diseases and harsh environmental conditions (ex. GM cotton for producing clothing – plants used in production of biofuels and biodegradable plastic – decorative plants – plants, animals and microorganisms developed to assist in the production of cosmetic ingredients

Next, we continued provision of other information – a table with scientific facts about GMO appeared on respondents' screens. It presented state of scientific knowledge about benefits and risks associated with GMO. Subjects were asked to indicate which of the statements are new information for them, so we could measure what type of information respondents encountered. Statements were presented in

pairs: every two sentences in a sequence were a positive and negative side of the same GMO related issue. Depending on a treatment, respondents were either always first informed about the positive information, or a negative information. Therefore, sequence of information presented shall not influence the overall stated preferences. For exact translation, see Appendix 2.

DCE attributes and levels

The choice experiment was designed to elicit Poles' preferences on policies regarding GMO's presence on the market and labelling of such products. The hypothetical policies were described using four attributes representing market segments for which regulations differ: GM food intended for direct consumption, food produced with the help of GMO but not containing any modified genes (e.g., processed foods, GMO used for fodder), pharmaceuticals and commercial products. Aforementioned categories of products can be conceptualized by consumers. Current EU regulations require that food products are obligatory labelled, other categories might be labelled voluntarily. Different regulations that can potentially be applied to the product categories represented levels of the DCE.

Table 2. Description of attributes, levels in potential policy scenarios

Attribute	Levels	Explanations
Food for direct consumption	– labeling ban (no labels) – voluntary labelling – obligatory labelling – banning GMO from the market Reference levels (status quo): obligatory labeling – food voluntary labeling – processed food, commercial and pharmaceutical products	**(i) banning GMO from the market** GMO products cannot be marketed and sold in Poland.
Processed foods not directly consumed by humans		**(ii) allowing GMOs on the market, *labeling ban (no labels)*** GMO products, after testing for safety, can be marketed and sold in Poland. Because GMO and non-GMO products are considered to be equivalent, **labelling both kinds of products is banned**, as it could result in unfair competition.
Commercial products		**(iii) allowing GMOs on the market, *voluntary labeling)*** GMO products, after testing for safety, can be marketed and sold in Poland. Labelling of products is not obligatory, but producers

		are allowed to label it voluntarily (ex. as containing GMO or GMO-free).
Pharmaceutical products		**(iv) allowing GMOs on the market, *obligatory labeling*** GMO products, after testing for safety, can be marketed and sold in Poland. **Labelling GMO** products is **obligatory**.
Cost	10, 20 50, 100 PLN [0 PLN for SQ]	annual cost for respondent's household

Respondents decided between status quo and two variants of new policy regarding the four products categories. The new policy could be more or less restrictive including banning GM products from the market, obligatory labeling, voluntary labeling, and labeling ban. One of the options was always the status quo, with current regulations that require all GM food products to be labelled and allow voluntary labelling for other product categories. Figure 1. Presents translation of a choice card.

The following explanation of current policy and potential changes was presented to respondents to ensure that they understand the choice task:

Use of genetic engineering, including genetic modifications and control over modified plants and animals, is regulated by law. However, significant differences in legislation can be observed in different countries, especially between the EU and the USA. In the EU and Poland few crops are allowed for cultivation, but import and sale of many other GMOs is allowed as well.

GMO food

Currently, food and feed containing GMOs are **required to be labelled**.

In practice, these labelling requirements do not apply to GM food/feed products in a proportion no higher than 0.9 percent of the food/feed if this presence is adventitious or technically unavoidable.

GMO used in production of food, pharmaceutical and commercial products

Food made with help of GMO or from animals or microorganisms feed with **GMO is not required to be labelled**, as it does not contain GMOs. Pharmaceutical and commercial products are not required to be labelled either.

Voluntary labeling

Currently in Poland producers are **allowed to voluntary label products** as „GMO-free" or „produced without use of GMOs". Similar regulations exist in other European countries.

For comparison, regulations in the USA banned such labelling, as it suggests that there is a significant difference between GMO-free and GMO products (and according to current stage of scientific knowledge – there is no such difference).

Figure 1. Example of choice card (translation)

Your choice:	☐	☐	☐
	Option 1	Option 2	Status quo
Food	voluntary labeling	obligatory labeling	obligatory labeling
Processed foods	labeling ban (no labels)	obligatory labeling	voluntary labeling
Pharmaceutical products	obligatory labeling	labeling ban (no labels)	voluntary labeling
Commercial products	banning from the market	voluntary labeling	voluntary labeling
Yearly cost to your household:	50 PLN	10 PLN	0 PLN

Follow-up questions, risk perceptions

The survey ended with follow-up questions on knowledge, GMO attitudes post-survey, risk attitudes, and socio-demographic questions. The knowledge was again measured by self-assessment and with repeated quiz questions. We asked subjects to compare their knowledge on the topic before and after taking part in the study. Risk perceptions were measured with a general question to intuitively assess how risky/beneficial is genetic engineering of organisms used: as food, in food production (not directly

consumed by humans), to produce pharmaceuticals, and commercial products. Socio-demographic variables collected at the end of the survey include household size and composition (number of children), sex, age, highest educational qualification, household income, residence (postal code).

3.3. Econometric framework

4. Results and discussion

The preferences and WTP are estimated using (1) the mixed-logit model, to represent consumers' general preferences for labelling of the four GMO product categories, (2) the latent class model, to gain an insight into distinct clusters of preferences, and (3) the hybrid choice model used to provide an insight into the main drivers of consumers' preferences: objective knowledge, self-assessed knowledge, risk perceptions, informed purchasing decisions, and a general attitude towards genetic modifications.

Table 1 presents the choice modelling results. The model is estimated in WTP-space, parameters are interpreted as WTP for a change in the attribute to this level relative to a baseline of no change in labelling policy.

Table 3. Results of the MXL models in WTP-space (in EUR) representing consumers' general preferences for labelling of the four GMO product categories

	Mean	**St. Dev.**
Status quo	9.54***	57.42***
	(1.28)	(2.14)
GM Food - voluntary label	-26.38***	24.22***
(vs. obligatory label)	(1.06)	(1.02)
GM Food - no label	-37.97***	30.91***
(vs. obligatory label)	(1.44)	(1.32)
GM Food - ban	-7.14***	27.56***
(vs. obligatory label)	(0.84)	(1.09)
GM Food processing - obligatory label	6.84***	9.97***
(vs. voluntary label)	(0.72)	(0.94)
GM Food processing - no label	-7.49***	8.45***
(vs. voluntary label)	(0.83)	(1.23)
GM Food processing - ban	-0.92	18.74***

(vs. voluntary label)	0.81	(1.05)
GM Pharmaceuticals - obligatory label	7.31***	9.03***
(vs. voluntary label)	(0.71)	(0.86)
GM Pharmaceuticals - no label	-6.35***	9.58***
(vs. voluntary label)	(0.81)	(1.22)
GM Pharmaceuticals - ban	-3.02***	19.63***
(vs. voluntary label)	(0.83)	(1.36)
GM Commercial products - obligatory label	0.74	8.77***
(vs. voluntary label)	(0.72)	(1.16)
GM Commercial products - no label	-1.04	8.35***
(vs. voluntary label)	(0.76)	(2.44)
GM Commercial products - ban	-7.14***	18.15***
(vs. voluntary label)	(0.84)	(1.74)
- Yearly cost per household (in 100 PLN)	3.36***	18.16***
	(073)	(0.97)
Model diagnostics		
LL at convergence	-54311.31	
LL at constant(s) only	-77091.29	
McFadden's pseudo-R^2	0.2955	
Ben-Akiva-Lerman's pseudo-R^2	0.5503	
AIC/*n*	1.3599	
BIC/*n*	1.3737	
n (observations)	80052	
r (respondents)	6671	
k (parameters)	119	

Notes: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. Parameter estimates represent WTP expressed in EUR a year per household. Standard errors provided in parentheses. All parameters were assumed to be normally distributed with the exception of the cost, which was assumed log-normally distributed (estimated coefficients of the underlying normal distribution provided). The model controls for scale (variance of the error term of utility function) differences between treatments. The scale parameters were skipped for brevity – full results are available in the online supplement to this paper.

The coefficient on the status quo is positive and significant, likely implying people's support for the current labelling policy of the GM products. The highest absolute values of WTP are observed for the food category. The weakest preferences are observed for commercial products, for which people are mostly indifferent between various policies. For all product categories, obligatory labelling is preferred to voluntary labels and to no labelling. People dislike banning of the GM products from the market, with an expectation of processed food, in which case they are indifferent between obligatory labelling and banning.

The willingness to pay expressed appear negligible for all but food category, when compared with households yearly spending on these categories. In the year of this study, the average household in Poland spent between 1700-2000 euro a year on foods and beverages. The willingness to accept of 40 euro a year for no labeling of GMO foods corresponds to roughly 2% increase in the amount spend.

Table 4. The results of the latent class model with three classes, presented in WTP-space (in EUR)

	Class 1 - Mean	**Class 2 - Mean**	**Class 3 - Mean**
Status quo	-130.38***	36.56***	3.63***
	(10.01)	(3.27)	(1.34)
GM Food - voluntary label	-19.91***	-19.01***	-26.61***
(vs. obligatory label)	(2.37)	(1.76)	(1.46)
GM Food - no label	-29.78***	-25.46***	-35.70***
(vs. obligatory label)	(3.01)	(2.25)	(1.89)
GM Food - ban	8.61***	-12.36***	3.38***
(vs. obligatory label)	(1.90)	(1.43)	(0.85)
GM Food processing - obligatory label	5.27***	4.92***	7.56***
(vs. voluntary label)	(1.86)	(1.20)	(0.94)
GM Food processing - no label	-9.41***	-2.37*	-6.71***
(vs. voluntary label)	(1.98)	(1.29)	(1.02)
GM Food processing - ban	10.98***	-5.04***	3.16***
(vs. voluntary label)	(1.90)	(1.44)	(0.92)
GM Pharmaceuticals - obligatory label	5.80***	4.71***	9.14***
(vs. voluntary label)	(1.80)	(1.17)	(0.95)
GM Pharmaceuticals - no label	-6.91***	-5.73***	-4.22***
(vs. voluntary label)	(1.92)	(1.36)	(0.98)
GM Pharmaceuticals - ban	8.68***	-7.43***	2.28**
(vs. voluntary label)	(1.88)	(1.46)	(0.94)
GM Commercial products - obligatory label	2.38	0.24	1.88**
(vs. voluntary label)	(1.77)	(1.18)	(0.89)
GM Commercial products - no label	-1.29	0.21	-0.73
(vs. voluntary label)	(1.79)	(1.18)	(0.92)
GM Commercial products - ban	8.27***	-10.42***	-3.40***
(vs. voluntary label)	(1.86)	(1.57)	(0.94)
- Yearly cost per household (in 100 PLN)	7.45***	28.54***	17.27***
	(0.58)	(1.92)	(0.80)
Probability model	**Class 1**	**Class 2**	**Class 3**
Cons	-4.86***	7.04***	0.0000
	(0.89)	(0.76)	
Average class probabilities	**Class 1**	**Class 2**	**Class 3**

(%)	25.2965***	43.2173***	31.4862***
	(0.6562)	(0.7376)	(0.6951)
Model diagnostics			
LL at convergence	-56453.32		
LL at constant(s) only	-77091.29		
McFadden's pseudo-R^2	0.2677		
Ben-Akiva-Lerman's pseudo-R^2	0.5374		
AIC/*n*	1.4115		
BIC/*n*	1.4166		
n (observations)	80052		
r (respondents)	6671		
k (parameters)	44		

Notes: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively. Parameter estimates represent WTP expressed in 100 PLN a year per household. Standard errors provided in parentheses.

In the latent class model, following Costa-Font et al. (2008) observation, we expected to have three classes of preferences. Class 1 represents anti-GM preferences: around 25% of respondents dislikes current policy, requests banning of all GM products or obligatory labelling of GM food, processed food and pharmaceutical products. Class 2 (43.22%) shows preferences of GM-accepters, who oppose banning o the GM products from the market. They approve current policy, but still prefer obligatory labeling of all product categories but commercial ones. Class 3 stands between Classes 1 and 2. 31.48% of the respondents, assigned to the Class 3, prefer banning food, processed food and medical products, but accept commercial products. They also want obligatory labelling of all GM products.

Table 5a. The results of the hybrid choice model, presented in WTP-space (in EUR)

			Interactions of means with LV:				
	Means	**St. Dev.**	**LV 1**	**LV 2**	**LV 3**	**LV 4**	**LV 5**
Status quo	5.48***	58.15***	14.54***	-7.77***	-5.76***	6.56***	-0.9
	(1.31)	(2.2)	(2.65)	(1.12)	(1.37)	(1.28)	(1.38)
GM Food - voluntary label	-28.07***	15.25***	-9.34***	1.16	-0.17	-0.18	-12.24***
(vs. obligatory label)	(1.08)	(1.24)	(1.51)	(0.76)	(0.86)	(0.85)	(0.96)
GM Food - no label	-39.31***	19.91***	-12.54***	0.73	0.65	0.98	-14.45***
(vs. obligatory label)	(1.43)	(1.52)	(1.84)	(0.9)	(0.97)	(0.99)	(1.09)
GM Food - ban	-6.03***	17.52***	-4.65***	3.02***	8.02***	0.76	12.71***
(vs. obligatory label)	(0.74)	(1)	(1.06)	(0.66)	(0.84)	(0.76)	(0.89)
GM Food processing - obligatory label	6.96***	6.26***	2.52***	-0.39	0.52	0.86	2.7***
(vs. voluntary label)	(0.74)	(0.9)	(0.98)	(0.68)	(0.79)	(0.72)	(0.81)
GM Food processing - no label	-7.3***	4.11***	0.5	-0.96	-0.3	0.48	-2.77***
(vs. voluntary label)	(0.81)	(0.85)	(1.06)	(0.72)	(0.85)	(0.79)	(0.86)
GM Food processing - ban	-0.4	11.78***	-3.13***	1.11	5.81***	0.29	8.67***
(vs. voluntary label)	(0.78)	(0.95)	(0.99)	(0.7)	(0.85)	(0.76)	(0.88)
GM Pharmaceuticals - obligatory label	7.22***	6.52***	3.73***	-0.92	-0.55	-0.3	3.5***
(vs. voluntary label)	(0.72)	(0.97)	(0.99)	(0.66)	(0.78)	(0.71)	(0.79)
GM Pharmaceuticals - no label	-6.64***	8.14***	-0.07	0.64	0.07	1.33*	0.14
(vs. voluntary label)	(0.8)	(0.97)	(0.95)	(0.72)	(0.85)	(0.77)	(0.86)
GM Pharmaceuticals - ban	-2.51***	11.8***	-2.63**	0.81	5.6***	-1.15	7.58***
(vs. voluntary label)	(0.79)	(1.12)	(1.06)	(0.71)	(0.87)	(0.78)	(0.88)
GM Commercial products - obligatory label	0.98	6.9***	1.64*	0.31	1.93**	-0.01	-0.51
(vs. voluntary label)	(0.72)	(0.88)	(0.88)	(0.66)	(0.79)	(0.73)	(0.79)
GM Commercial products - no label	-1.12	7.46***	0.63	-0.48	0.15	-0.07	-0.73
(vs. voluntary label)	(0.74)	(0.88)	(0.9)	(0.68)	(0.81)	(0.74)	(0.83)
GM Commercial products - ban	-6.78***	12.99***	-4.48***	1.48**	5.09***	0.14	4.46***
(vs. voluntary label)	(0.84)	(1.06)	(1.04)	(0.72)	(0.87)	(0.78)	(0.88)
- Yearly cost per household (in 100 PLN)	-3.24***	0.43***	0.29***	-0.05***	-0.04***	-0.01	-0.02
	(0.03)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)

Model diagnostics	
LL at convergence	-274018.63
LL at constant(s) only	-77091.292
McFadden's pseudo-R^2	-2.5544693
Ben-Akiva-Lerman's pseudo-R^2	0.5461865
AIC/*n*	6.8543854
BIC/*n*	6.8932638
n (observations)	80052
r (respondents)	6671

Table 5b. Extraction from measurement equations of the hybrid choice model, presented in WTP-space (in EUR)

LV1		LV2	LV3	LV4	LV5
Quiz score (OLS)		Self-assessed knowledge	Perceived risks	Buying habits	Acceptability
Cons.	0.00	**General (OP)**	**Food (OP)**	**Price (OP)**	**Food (OP)**
	(0.01)	1.04***	1.61***	0.00	1.23***
LV1	0.23***	(0.02)	(0.03)	(0.02)	(0.03)
	(0.02)	**Health (OP)**	**Processed food (OP)**	**Quality (OP)**	**Processed food (OP)**
Sigma	-0.03***	-2.23***	2.25***	0.70***	1.23***
	(0.01)	-0.05	(0.05)	(0.02)	(0.03)
		Environment (OP)	**Pharmaceuticals (OP)**	**Local (OP)**	**Pharmaceuticals (OP)**
		-2.74***	1.73***	0.82***	1.03***
		(0.06)	(0.04)	(0.03)	(0.03)
		Benefits (OP)	**Commercial (OP)**	**Environmental (OP)**	**Commercial (OP)**
		-1.5***	1.36***	0.87***	0.84***
		(0.03)	(0.03)	(0.03)	(0.02)
		Risks (OP)			**Safe for:**
		-2.27***			**Health (OP)**
		(0.05)			0.88***
		Law (OP)			(0.02)
		-1.31***			**Environment (OP)**
		(0.03)			0.74***
		Facts known (OLS)			(0.03)
	Cons.	0.02*			**Acceptability of modifications in:**
		(0.01)			**Plants (OP)**
	LV1	0.4***			1.57***
		(0.01)			(0.03)
	Sigma	-0.07***			**Microorganisms (OP)**
		(0.01)			1.32***
					(0.03)
					Insects (OP)
					1.36***
					(0.03)
					Fish (OP)
					1.60***
					(0.04)
					Mammals (OP)
					1.37***
					(0.03)

In the hybrid choice model, we constructed five latent variables: objective knowledge, self-assessed knowledge, risk perceptions, informed purchasing decisions, and general negative attitude towards genetic modifications. The following survey questions were grouped into latent variables:

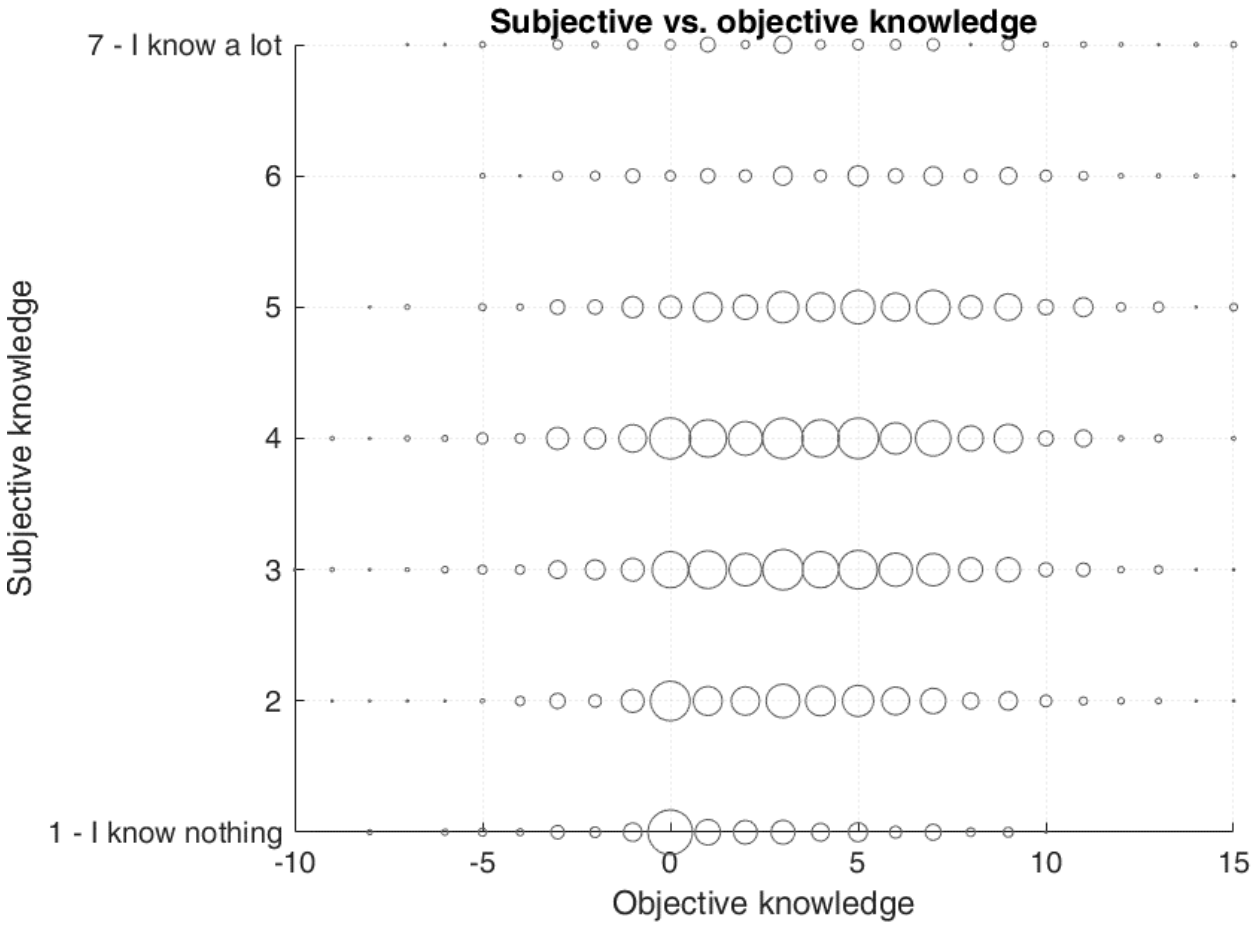
- LV1[objective knowledge]: Quiz result (Q5)
- LV2[self-assessed knowledge]: Q3, Q4, Q7 - number of "I heard about it before" responses
- LV3[risk attitudes]: Q15-23
- LV4[environmental concern]: Q2b,c,d
- LV5[general attitudes]: Q6a,b,c,d, Q8, Q13

First latent variable is a result of the quiz (see Appendix1). People who achieved better quiz result (know relatively more), are also more likely to accept current policy. For GM food, they prefer current policy to any other option. For the remaining categories, they disapprove prohibition of GM processed food, pharmaceutical and commercial products from the market.

The predictive power of self-assessed knowledge (LV2) is weaker than that of objective knowledge. A group of people who think they know a lot about GM products, are less likely to accept current policy. They have higher WTP for banning of GM food and commercial products from the market.

Inspired by Fernbach et al. (2019), we further investigated the relationship between subjectively and objectively measured knowledge. Figure 2 presents this relationship. We found that for a large share of respondents their self-assessment of knowledge is consistent with their state of knowledge. The group of information searchers is large (75%).

Figure 2. Relationship between self-assessed knowledge about the GMO and quiz result



Risk perceptions are represented by LV3, the results reveal that people who consider risks of GM products to be high want to ban such products from the market. This result is clear and solid for all product categories. Similar pattern is observed for people with negative attitudes towards genetic modifications and respondents who express concerns about safety of GM products (LV5). In addition, people with general negative attitude want to be informed about the GM content of all foods.

Last, LV 4 indicates consumers who pay attention to quality, local production, or during everyday shopping. These people are likely to accept current policy.

5. Summary and conclusions

The results provide monetary valuation of preferred characteristics of new policies; they can be used in cost-benefit analyses concerning future GMO regulation. We find that while the majority of people prefer GM products to be labelled, they also disapprove banning of the GM products from the market. The preferences against non-labeled GM-products is strongest for the non-processed foods, and lighter for processed food, pharmaceuticals and commercial products. We would like to conclude by highlighting the role that stated-preference studies can have in optimizing the labelling policies. We also offer recommendations regarding the construction of future GMO-related policies, including role of information, knowledge, risk and trust.

Large part of existing literature reveals general negative attitudes toward GM products, especially foods. Our findings show that attitudes are only a partial predictor of revealed preferences, expressed in terms of WTP. Consumers mainly prefer GM free products, until the point that they must pay a high premium for labelling policies. This observation is in line with Costa-Font et al. (2008) review, but it also contests findings of studies based solely on attitudes, rather than economic experiments. This relates also to recent studies conducted in Poland, such as Rzymski and Królczyk (2016), that present strong public opposition towards production and distribution of GM food products on the Polish market, which we do not find. Our estimates can be compared with spending for the four product categories. For food products it is roughly 2% of such spending. This might or might not cover the costs of maintaining the current GMO labelling policy, which could be calculated to optimized the regulations when policy costs are available.

We see great value in revealing economic preferences rather that attitudes: public preferences are stable over time, unlike attitudinal measures, which tend to be susceptible to large shifts over time and allow for subjective interpretation. For example, Ichim (2021) claims that more favorable attitudes

of the citizens toward GMOs supports a new regulatory framework in the European Union, given that level of concern for GM ingredients decreased substantially between 2005 and 2019. The 2010 Eurobarometer study asked whether one agreed with statement about GM foods safety for his health, 63% disagreed. In the 2019 survey, GMO safety was assessed relative to other food safety concerns (antibiotics, pesticides etc.) and it was in the middle of the presented ranking, with 27% Europeans perceiving it as one of five most serious food related risk. This example shows, that proposed policy changes should not be based on attitudinal questions and separated from cost and benefit assessment.

In the introduction, we put four hypotheses, which we comment in the light of the new evidence presented in this paper. The preferences against non-labeled GM-products is strongest for the non-processed foods, and lighter for processed food, pharmaceuticals and commercial products. We propose that an incremental process of offering useful innovation, acknowledged by the general public, can built recognition, trust and overcome public opposition better that the scientific rhetoric of facts For example, introduction of enriched GM-food might be an unpopular decision in countries in which most people already get their required amount of nutrients and vitamins from a normal diet. Instead, introduction of cheaper medical or commercial products can be met with less resistance. Following Chern et al. (2003), we suggest that GMO labels that contain information of the benefits and purpose of the technology use could increase product acceptability.

Regarding the role of knowledge and information, we do not observe the level of overconfidence in knowledge self-assessment as shown by Fernbach et al. (2019). Instead, we observe that the majority of consumers fit into the group of information searchers with lightly negative attitudes. They have limited knowledge on the topic, but they are also willing to admit that it is so (Rzymski & Królczyk, 2016, find the same). People who achieved better quiz results (know relatively more about GMO), were also more in favor of the current policy. The predictive power of the self-

assessed knowledge is weaker than that of the objective knowledge. The preference for banning GM products from the market are impelled by the related risk attitudes and perceptions.

Currently, GM products have a small share of the market in Poland, mostly in for of vegetable oils from GM seeds (Twardowski, 2008). Consumers do not have experience with such products, which makes them susceptible to information and marketing. It is widely recognized that consumer response to marketing efforts with emotions, which is reflected in their purchases (Machleit & Eroglu, 2000). Fear can trigger a strong impulse response from consumers site (Loxton et al., 2020).

Latest Eurobarometer study shown, that Poles are amongst nation that were least likely to believe that 'to decide how risky something could be for you to eat, the EU relies on scientists to give expert advice' (Eurobarometer, 2019). Rodríguez-Entrena and Salazar-Ordóñez (2013) suggest that perceptions of risks and benefits could be modified through trust in institutions and researchers, which consumers in Poland might lack. Many important risk-related decisions are moderated by individuals' trust in government and trust in science (Bicchieri et al., 2021). Further work could benefit from stronger focus on the learning process element and information provisions within the survey, which can have important explanatory role in modeling of complex decision making.

Our results offer new insights into factors that shape the complex decision-making process with regard to GMO, by controlling respondents' objective and subjective level of knowledge, using various measures of risk aversion, perceptions of health and environmental risks/benefits, and controlling learning process within the survey. The interaction between these factors is important, as people's perception of uncertain threats/benefits is often biased compared to objective probabilities. Such biases can lead to decisions motivated by emotional responses, rather than by truthful preferences based on objective information.

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APPENDIX 1. True/False quiz – translation

We ask you to take a short quiz. Indicate whether the following statements are, in your opinion, true or false:

	True	False		Don't know
Genetically modified food can be transferred into genes of humans who eat them.		X		
Based on currently available research results, it can be stated that GM food poses no greater risk to human health than conventional food	X			
Transfer of genes between species cannot occur in nature.		X		
It is impossible to transfer genes between animals and plants.		X		
Genes of traditionally bred plants have not changed for thousands of years.		X		
Genetically modified plants can have greater resistance to pests, diseases and environmental conditions.	X			
Genetically modified plants can have improved nutrition content or contain less of hazardous substances.	X			
Genetically modified crops allow for reduction of chemical fertilizers use.	X			
Use of genetically modified plants reduces farmland biodiversity.	X			
Firms, that engineered genetically modified crops, are owners of GM seeds and farmers are obliged to pay for use these crops.	X			
Products produced with the help of GMO are available on the Polish market.	X			
In Poland GM food and GMO used for fodder are subject to mandatory labelling.	X			
In Poland food and fodder produced with the help of GMO, but not containing any modified genes, are subject to mandatory labelling.		X		
In Poland pharmaceuticals and commercial products produced with the help of GMO are subject to mandatory labelling.		X		
GM foods must undergo a health safety assessment prior to being awarded certification for distribution to the market.	X			

APPENDIX 2. State of knowledge on GMO – translation

Current state of knowledge – what we know about GMO?

		This information is new for me	I heard about this before
1a	Crops can be genetically modified so they are resistant to pest, certain diseases, and harsh climatic condition.		
1b	It happens that pests and diseases evolve and adapt to genetically modified crops.		
2a	Genetic modifications can result in increased crop yields, produce selected desirable traits and improve nutritional value of foods.		
2b	Firms, that engineered genetically modified crops, are owners of GM seeds and farmers are obliged to pay for use these crops.		
3a	Genetically modified crops allow for reduction of chemical fertilizers, herbicides and pesticides use.		
3b	Certain genetically modified crops are resistant to chemical treatments used to destroy unwanted vegetation (all other plants) from agricultural fields. The reduction in the spectrum of other plants, that compete with crops, contribute to decreasing number of bugs and birds that depend on these unwanted plants and weeds.		
4a	Genetic modifications contribute to creation and production of new medicines.		
4b	There is a risk of the engineered genes from non-for-food GM plants being introduced to GM plants used for food.		
5a	Many genetic modifications/ engineering can be obtained with traditional methods (ex. crossings). Common, conventionally breed plants are genetically modified with used of traditional methods.		
5b	There is little probability that certain genetic modifications obtained with advanced modern methods would occur in natural environment.		
6a	It happens rarely, but gene mutations do occur naturally. There are natural mechanisms of gene transfer between species (ex. by viruses).		
6b	There is a risk that modified genes 'escape' from experimental fields and potentially introduce the engineered genes into wild populations. This process is irreversible.		
7a	There is no evidence of genetically modified crops being more likely to become invasive species (uncontrolled spreading).		
7b	Invasive species, that quickly spread and dominate when introduced to a new habitat, are one important treat to some existing, naturally occurring wildlife. Theoretically, some GM species may become invasive.		
8a	Safety testing is always done on genetically modified foods before it is launched onto the market.		

8b	Analysis of genetically modified foods' safety for health includes toxicity and allergy tests, but not on comparison of all differences between GMO and its traditional equivalent.		
9a	GMO food is digested just as its traditional equivalent. Genetically modified gens' from food cannot be transferred to humans and change people's DNA. All research studies available show that it is improbable that GMO food creates more risks than traditional food.		
9b	Assessment of genetically modified foods' safety is based on comparison with traditional equivalents, but this traditional food does not need to be safe for health either (especially when one consumes too much of it). This method is incomparable to testing safety of other products ex. testing safety of new drugs.		

In treatments, the above facts were presented in matching pairs marked as a-b. The sequence was either that positive information went first (a before b) in T2.1, or that negative facts preceded positive ones (b before a) in T2.2.

University of Warsaw
Faculty of Economic Sciences
44/50 Długa St.
00-241 Warsaw
www.wne.uw.edu.pl