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ORIGINAL RESEARCH

Public optimism towards nanomedicine

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Massimo Bottini[1,2]
Nicola Rosato[2,3]
Fulvia Gloria[4]
Sara Adanti[4]
Nunziella Corradino[4]
Antonio Bergamaschi[5]
Andrea Magrini[4]

[1]Sanford Burnham Medical Research Institute, La Jolla, CA, USA; [2]Department of Experimental Medicine and Biochemical Sciences, University of Rome Tor Vergata, Rome, [3]IRCCS-Neuromed Institute, Isernia, [4]Department of Biopathology and Imaging Diagnostics, University of Rome Tor Vergata, Rome, [5]Institute of Occupational Medicine, Catholic University of The Sacred Heart, Rome, Italy

Background: Previous benefit–risk perception studies and social experiences have clearly demonstrated that any emerging technology platform that ignores benefit–risk perception by citizens might jeopardize its public acceptability and further development. The aim of this survey was to investigate the Italian judgment on nanotechnology and which demographic and heuristic variables were most influential in shaping public perceptions of the benefits and risks of nanotechnology.

Methods: In this regard, we investigated the role of four demographic (age, gender, education, and religion) and one heuristic (knowledge) predisposing factors.

Results: The present study shows that gender, education, and knowledge (but not age and religion) influenced the Italian perception of how nanotechnology will (positively or negatively) affect some areas of everyday life in the next twenty years. Furthermore, the picture that emerged from our study is that Italian citizens, despite minimal familiarity with nanotechnology, showed optimism towards nanotechnology applications, especially those related to health and medicine (nanomedicine). The high regard for nanomedicine was tied to the perception of risks associated with environmental and societal implications (division among social classes and increased public expenses) rather than health issues. However, more highly educated people showed greater concern for health issues but this did not decrease their strong belief about the benefits that nanotechnology would bring to medical fields.

Conclusion: The results reported here suggest that public optimism towards nanomedicine appears to justify increased scientific effort and funding for medical applications of nanotechnology. It also obligates toxicologists, politicians, journalists, entrepreneurs, and policymakers to establish a more responsible dialog with citizens regarding the nature and implications of this emerging technology platform.

Keywords: nanotechnology, nanomedicine, nanodrugs, benefit perception, risk perception, societal impact

Introduction

Lay people are the ultimate beneficiaries of the advancement of science, and their benefit–risk perception can be influenced by adverse events, negative media coverage, and fractious political debate. A negative public opinion can seriously jeopardize further technological progress. In this regard, social scientists have been recording and analyzing the psychological responses of lay people following technological and health disasters (like the ones associated with nuclear power and genetically modified organisms) to gather information about the mental processes driving societal benefit–risk perceptions of new technologies. Through such efforts politicians, scientists and policymakers are better prepared to cope with public responses in the advent of new catastrophic scenarios.

Correspondence: Massimo Bottini
Sanford Burnham Medical Research Institute, 10901 North Torrey Pines Road, La Jolla, CA 92037, USA
Tel +1 858 646 3100 ext 3063
Fax +1 858 795 9225
Email mbottini@sanfordburnham.org

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Although relatively new, nanotechnology has already been applied in several fields, such as electronics, development of alternative energies, photonics, medicine and many others. In particular, approximately one decade ago, several research groups gave birth to a new discipline termed "nanomedicine," by using the tools and knowledge of nanotechnology to fabricate more efficient, safer, and cheaper drugs than was possible using traditional methods.[1] As nanotechnology has been developing, we have been witness to an unprecedented interest of social scientists in understanding the public benefit–risk perception of nanotechnology.[2–16] Because it is a relatively new science, with applications mainly at the exploratory stage and largely confined to academic laboratories, nanotechnology offers a unique opportunity to understand the public perception before it becomes part of everyday life and without the intersect of any nanotechnology-derived disasters.[17]

To date, several surveys have been carried out in many countries worldwide to investigate public attitudes toward nanotechnology. These investigations have taken the form of purely descriptive studies[2,3,6] or theory-driven models,[9–11] and have focused on the comprehension of the predisposing factors that drive the public benefit–risk perception of nanotechnology. These predisposing factors can be clustered as heuristic, demographic, attitudinal, or informative, and can attempt to shape the benefit–risk perception of lay people through both internal and external processes (see Figure 1). Internal processes are affect-driven and composed of, to use the words of Cris Toumey, "the landscape of values, beliefs, concerns and other strong sentiments that were established in people's hearts long before most people heard or cared about nanometers, van der Waal's forces or carbon nanotubes", whereas the external processes are the ensemble of media information about risks and benefits of nanotechnology.[18]

Patterns reported in the conventional risk-perception literature predict that nonfamiliarity and psychometric variables (such as fear, nonobservability, novelty, and involuntariness of exposure) may trigger a high degree of public concern.[8,19] However, this perception model does not appear to explain the public attitude toward nanotechnology. Indeed, social investigations have shown that, despite a very low public familiarity with nanotechnology and the intrinsic intangible and invisible nature of nanotechnology-derived objects, a positive judgment of nanotechnology was diffused in the surveyed countries. This result suggested that other predisposing factors are more likely to affect nanotechnology perception rather than the conventional heuristic ones (familiarity and psychometric variables).[12]

Recently, social scientists have begun to study how the predisposing factors interact with one another to influence the public benefit–risk perception of nanotechnology. Investigations have focused mainly on demographic (eg, religious beliefs, gender, race, education) and heuristic (eg, familiarity, psychometric parameters, cultural biases) variables. Scheufele et al investigated the influence of religious beliefs on nanotechnology acceptance in Europe and the US and found that lay people from more religious countries (such as the US, Ireland, and Austria) have a less positive judgment of nanotechnology than subjects from less religious countries (such as Denmark, Sweden, and France).[10] A study from Satterfield et al, based on the meta-analysis of data from previous investigations, validated the "familiarity hypothesis", according to which the perception of nanotechnology benefits outweighing the risks increases with the individual's level of familiarity.[12] However, this model should be treated with caution because it considers familiarity only as a variable influencing public perception. Surveys taking into account other variables in concomitance with familiarity have discredited the "familiarity hypothesis", highlighting the fact that people may be biased by their political, economic, and religious beliefs while gathering information. For instance, Kahan et al have explored how cultural biases control the familiarity-perception relationship.[9] In particular, they noted that the percentage of those seeing nanotechnology benefits as overwhelming the risks increases with the familiarity among hierarchical individualists (pro commerce), whereas it decreases among egalitarian communitarians (anti commerce).

The data from a 2005 European survey on public perception of biotechnology, ie, the Eurobarometer 64.3 (EU 64.3), created a portrait of European citizens as optimistic about biotechnologies ("Europeans are generally optimistic about the contribution of technology to our way of life"), in particular about nanotechnology ("Europeans support the development of nanotechnology, pharmacogenetics, and gene therapy. All three technologies are perceived as useful to society and morally acceptable. Neither nanotechnology nor pharmacogenetics are perceived to be risky").[20] However the EU 64.3 did not investigate in detail the predisposing factors affecting the benefit–risk perception of nanotechnology and the pattern of the areas that lay people think would be (positively and/or negatively) impacted the most by nanotechnology in the near future.

In this work we describe a first survey carried out among 790 citizens of Rome to gather information about the Italian perception of nanotechnology. Rome is considered as representative of Italy and was chosen for our survey because it

is the most populous city in the country (more than 2.5 million inhabitants) and hosts people from all Italian regions. The picture that emerges from the present study is that Italian citizens, regardless of the limited familiarity with nanotechnology, showed optimism towards nanotechnology applications, especially those related to health and medicine (nanomedicine). Furthermore, statistical analyses were developed to determine the predisposing factors driving the public perception of the benefits and risks that nanotechnology would bring to certain areas of everyday life in the next two decades.

Materials and methods

Survey questionnaire

The survey was carried out during spring 2011 using a written questionnaire and face-to-face interviews with 790 citizens chosen randomly from four different urban areas of Rome. The questionnaire was anonymous and divided into six sections, comprising demographic characteristics, familiarity with nanotechnology, trust in science, social impact, benefits and risks, and benefit–risk perception (see Appendix).

Statistical analysis

Chi-square independence analysis, linear discriminant analysis (LDA), principal component analysis (PCA), and logistic regression analysis (LRA) were performed by SPSS Statistics (IBM Corporation, Armonk, NY).

Results

Demographic characteristics

The interviewees were mainly composed of people aged 20 to 40 years, uniformly distributed between males and females and with at least high school education. Seventy-eight percent of the surveyed citizens were Catholic (Figure 2A).

Familiarity with nanotechnology

Approximately 72% of Italian citizens have heard about nanotechnology, mainly from television and the Internet. However, approximately 80% of those who have heard about nanotechnology knew little about this scientific field. Most of the interviewees thought that nanotechnology may have the biggest use in medicine, whereas only approximately 38% of them were aware of nanotechnology-derived consumables. It is of note that 80% of aware people knew that electronic devices are made of nanotechnology, but a lower percentage knew that nanotechnology-derived particles (nanoparticles) are already present in drugs (15%) and beauty products (5%). Less than 5% knew that foods already contain nanoparticles (Figure 2B).

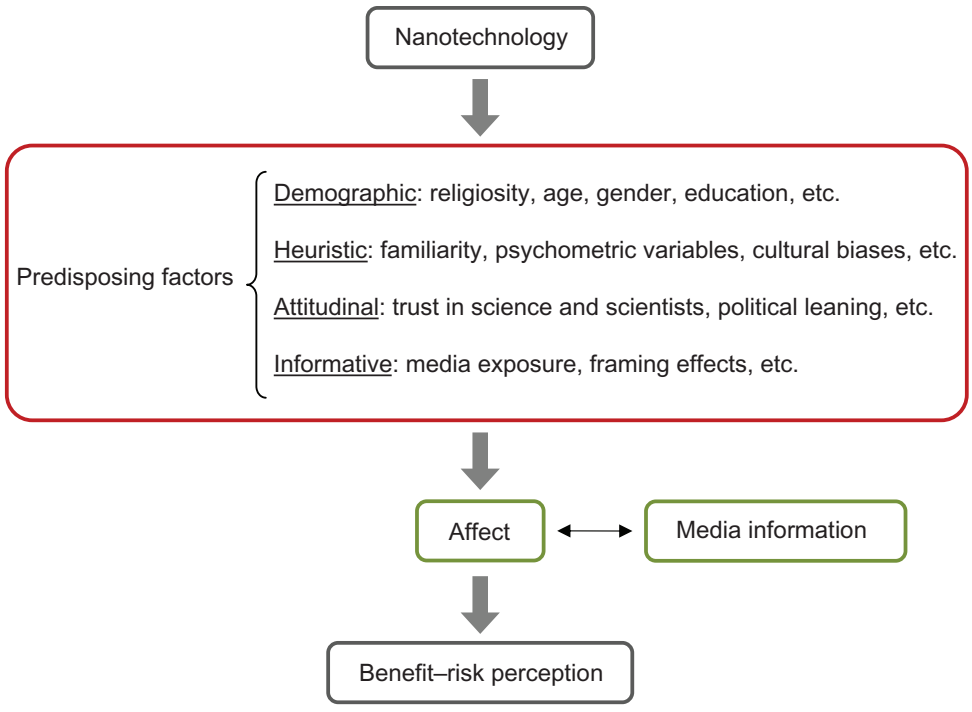

Figure 1 The perception of nanotechnology benefits and risks is influenced by personal predisposing factors (age, gender, education, familiarity, etc) directly through internal processes (affect) and indirectly through external processes (ensemble of media information related to nanotechnology). The affect-media information relationship is bidirectional. Affect may influence the information-seeking behavior of people, but, in return, information, especially that from media aimed to create feelings more than information, may shape our affective processes.

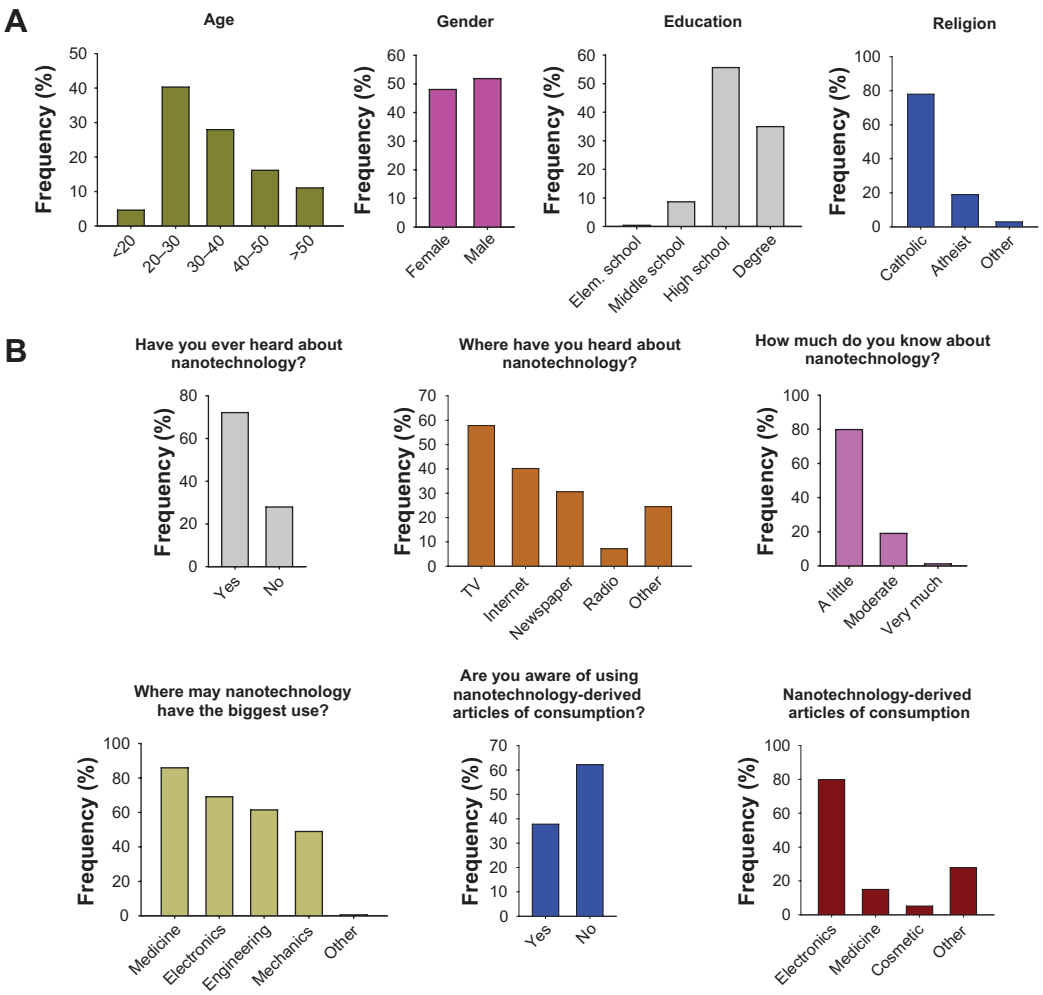

Figure 2 (**A**) Demographic characteristics. (**B**) Familiarity with nanotechnology.
Abbreviation: Elem. school, elementary school.

Trust in science

Italian citizens thought that science is very important to society (9.1 on a scale of 1–10), and they had fairly good trust in scientists (7 on a scale from 1–10).

Social impact

Almost all the interviewees believed that nanotechnology might have a strong economic and occupational impact (94%) and that the government should promote scientific research on nanotechnology (96%, Figure 3A).

Benefits and risks

Italian citizens believed that nanotechnology will bring the biggest benefits to health and medicine (84%), electronics (58%), and energy production (44%), whereas they saw the risks evenly distributed among pollution (36%), division among social classes (33%), increase of public expenses (32%) and human health (27%), as shown in Figure 3B.

Benefit–risk perception

The last section of the survey was divided into six areas to gather information about the public perception of nanotechnology. Almost all interviewees (88%) indicated that the presence of nanoparticles should be explicitly stated for consumables, and believed that it is necessary to create a commission of control to regulate the use of nanotechnology, especially with regard to health and environmental pollution. Sixty-four percent of these Italian citizens would purchase nanoparticle-based consumables but only if they did not have side effects. It is noteworthy that just 1% of the interviewees would never buy nanoparticle-based articles, and 72% would use drugs made of nanomaterials. Finally, almost all the surveyed citizens (92%) did not think they were sufficiently informed regarding nanotechnology and its benefits and risks (Figure 3C).

Statistical analysis

In order to understand which predisposing factor(s) principally shape the benefit–risk perception, we first analyzed the effects

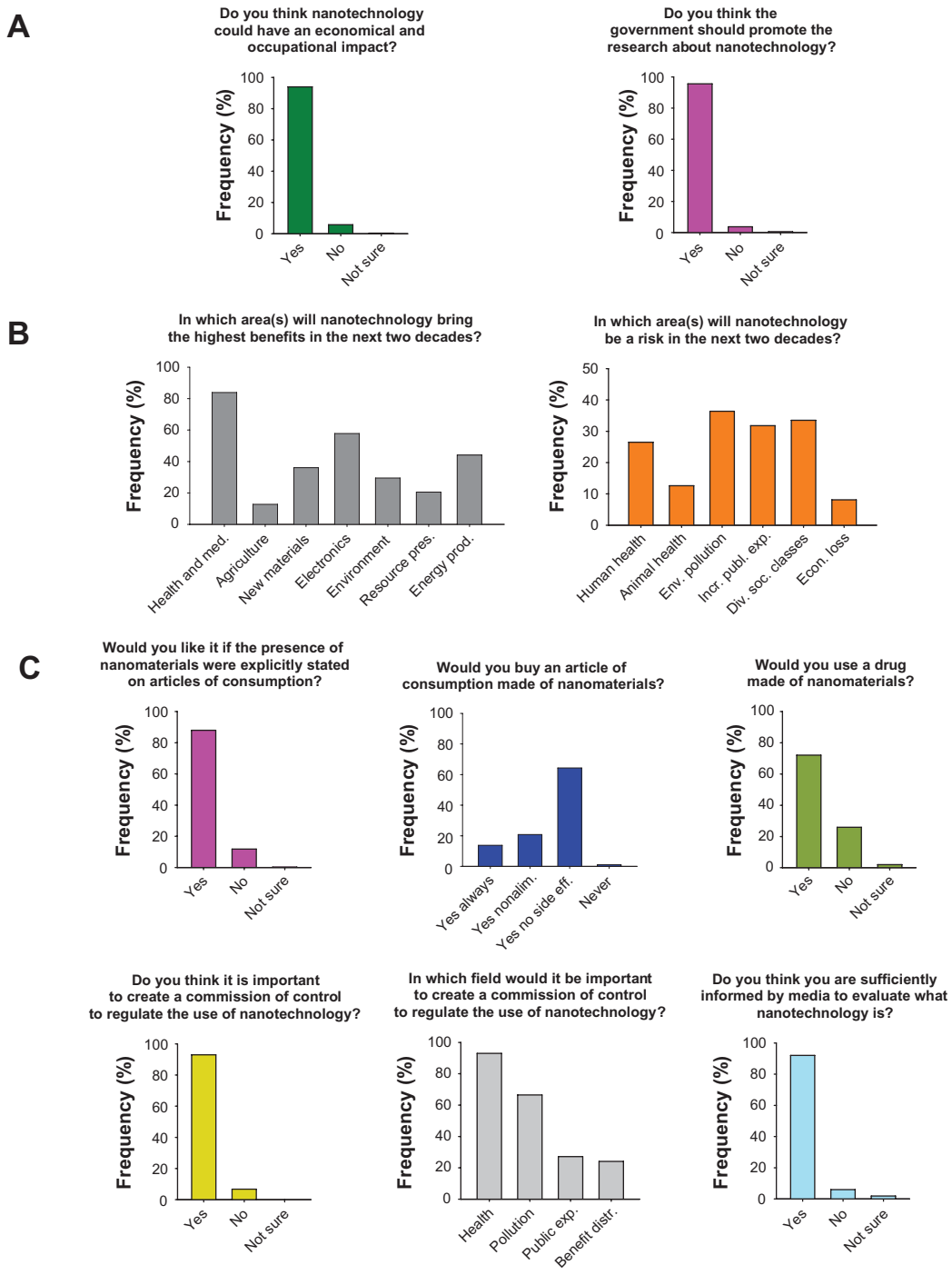

Figure 3 (**A**) Social impact. (**B**) Benefits and risks. (**C**) Risk and benefit perception.
Abbreviations: Benefit distr., benefit distribution; Div. soc. classes, division among social classes; Econ. loss, economic loss; Energy prod., energy production; Env. pollution, environmental pollution; Health and med., health and medicine; Incr. publ. exp., increase of public expenses; Public exp., increase of public expenses; Resource pres., resource preservation; Yes no side eff., yes but only if it is stated that the article does not elicit side effects; Yes nonalim., yes but only for nonalimentary articles.

of four demographic (religion, age, gender, and education) and one heuristic (knowledge) predisposing factors on the perception of the areas that would be (positively and negatively) affected by nanotechnology (Figure 4).

Male interviewees were more likely to foresee benefits of nanotechnology in the creation of new materials ($P = 0.007$) and the development of electronics ($P = 0.03$), whereas female interviewees were more optimistic about resource preservation ($P = 0.015$). In turn, education positively influenced the inclination of Italian interviewees to think that nanotechnology would bring benefits to the creation of new materials ($P = 0.003$) and to electronics ($P = 0.04$). On the other hand,

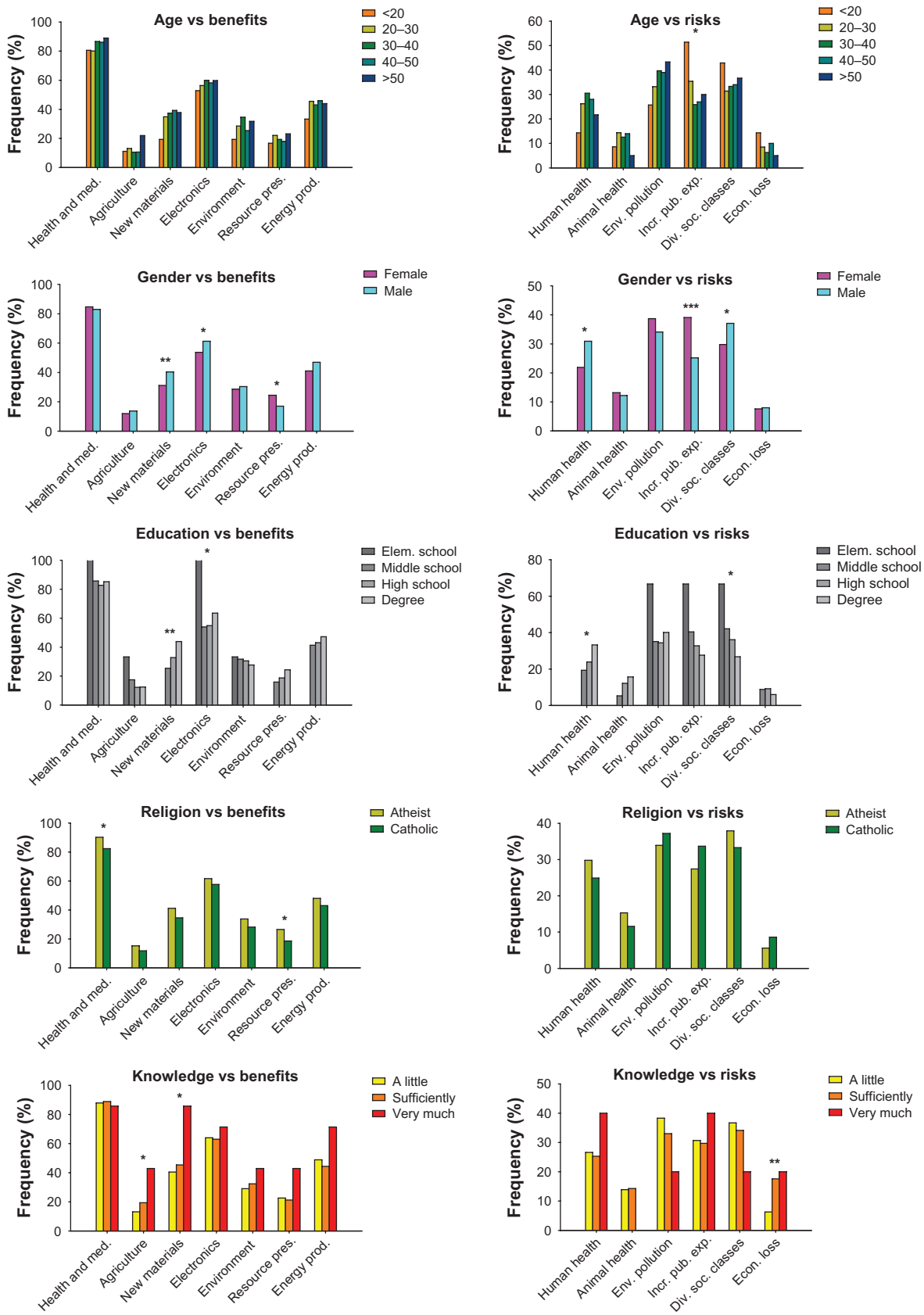

Figure 4 Impact of chosen demographic (age, gender, education, religion) and heuristic (self-estimated knowledge) predisposing factors on the perception of the areas that will be positively and negatively affected by nanotechnology in the next 20 years.

Notes: *$0.01 \leq P < 0.05$; **$0.001 \leq P < 0.01$; ***$P < 0.001$.

Abbreviations: Div. soc. classes, division among social classes; Econ. loss, economic loss; Energy prod., energy production; Env. pollution, environmental pollution; Elem. school, elementary school; Health and med., health and medicine; Incr. publ. exp., increase of public expenses; Resource pres., resource preservation.

religious beliefs negatively influenced the inclination to think that nanotechnology would bring benefits to the improvement of health and medicine ($P = 0.02$) and resource preservation ($P = 0.03$). (Self-estimated) knowledge of nanotechnology was positively correlated with the inclination to think that nanotechnology would bring benefits to agriculture ($P = 0.028$) and the creation of new materials ($P = 0.046$). Age did not influence any of the chosen benefit areas.

Older Italian interviewees showed lower concern about the risks that nanotechnology might bring to the increase of public expenses ($P = 0.043$). Male interviewees showed greater concern for the effects of nanotechnology on human health ($P = 0.01$) and division in social classes ($P = 0.047$), whereas female interviewees worried more about the increase in public expense ($P = 0.000$). A higher level of education correlated with greater concern about the effects of nanotechnology on human health ($P = 0.03$) and a lower concern about the effects of nanotechnology on the division in social classes ($P = 0.03$). (Self-estimated) knowledge of nanotechnology was positively correlated with the inclination to think that nanotechnology may cause economic loss ($P = 0.002$). No statistically significant effect of religious beliefs on perception of the risk of nanotechnology was found.

Figure 5 schematically depicts the statistically significant correlations between chosen predisposing factors and the areas that would be affected by nanotechnology in the next 20 years. We next performed a PCA to exclude potential biases due to correlations between predisposing factors and condense the predisposing factors to a smaller number of uncorrelated variables (principal components). The results of this analysis are reported in Table 1. The components

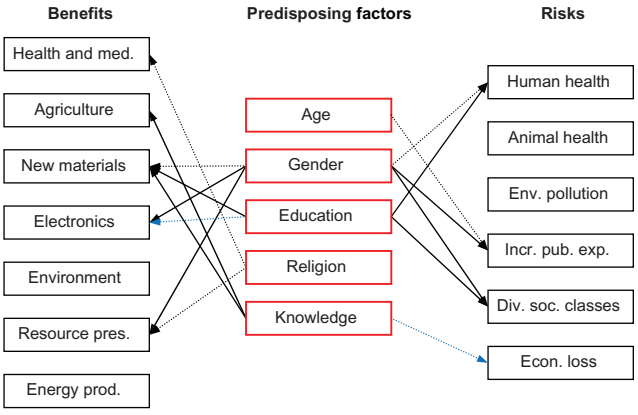

Figure 5 Statistically significant correlations between chosen predisposing factors and the areas that would be affected by nanotechnology in the next 20 years.
Note: The correlations removed by linear discriminant analysis and logistic regression analysis were depicted by black and blue dotted arrows, respectively.
Abbreviations: Div. soc. classes, division among social classes; Econ. loss, economic loss; Energy prod., energy production; Env. pollution, environmental pollution; Incr. publ. exp., increase of public expenses; Health and med., health and medicine; Resource pres., resource preservation.

Table 1 Variance described through factors calculated by principal component analysis

Component	**Total variance**	
	% of variance	**% of cumulative variance**
First	24.3	24.3
Second	23.4	47.7
Third	20.2	68.0
Component matrix		
Predisposing factors	**Component**	
	First	**Second**	**Third**
Age	0.550	–0.222	0.464
Gender	0.418	0.488	–0.627
Education	–0.386	0.668	0.0015
Religion	–0.028	0.613	0.634
Knowledge	0.767	0.251	0.039

extracted accounted for 68% of the total variability in the predisposing factors. The coefficient describing the first component suggested a significant correlation between knowledge, gender, education, and age, whereas those describing the second component suggested a significant correlation between religion, gender, and education, and those describing the third component suggested a significant correlation between religion, gender, and age.

Because PCA generated a strong correlation between the predisposing factors, we next performed an LDA in order to remove spurious correlations between the predisposing factors and the areas of benefits and risks. The correlations removed by LDA were depicted by dotted arrows in Figure 5. In particular, it is noteworthy that LDA removed the effect of religion on the perception of nanotechnology benefits. The cancellation of the religion-health and religion-resource preservation correlations following LDA could be due to the association of religion with age (third component) and gender (second and third components), respectively. In other words, the relation of religion with the two benefit variables may be spurious due to a correlation of religion with age and gender. LDA also removed the correlation between gender and the perception that new materials will gain benefits from nanotechnology. This result may be due to the association of gender with (self-estimated) knowledge (first component) and education (first and third components). Indeed (self-estimated) knowledge and education are both significantly correlated with the new material benefit variable. Furthermore, LDA removed some correlations between predisposing factors and risk variables. In particular, the role of age on the perception of the risks that nanotechnology might bring to the increase of public expenses was removed. This result could be due to the association of age with gender

(first and third components). Finally, LDA erased the correlation between gender and human health, probably due to the association between gender and education (first and second components).

In theory, LDA should be performed only if the independent variables (the predisposing factors in our case) have a normal distribution. However, LDA is still a robust statistical methodology even in cases in which independent variables are not normally distributed. In order to confirm our LDA-based results (Figure 5), we performed an LRA. LRA is more selective than LDA in removing spurious correlations between independent and dependent variables, and it usually has a number of outcomes lower than that given by LDA. The outcomes of LRA substantially matched those of LDA with just two exceptions. While LDA gave a significant correlation between gender and level of education, and the perception of the nanotechnology-derived benefits on new electronics, LRA only showed gender as an outcome significantly influencing the perception of the benefits of nanotechnology on electronics (ie, the correlation between education and electronics was removed). Furthermore, while LDA gave a significant correlation between the level of knowledge and perception of nanotechnology-derived risks on economic loss, LRA removed this correlation, thereby leaving nanotechnology-derived risks on economic loss significantly correlated with none of the chosen predisposing factors.

Discussion

In this study we report the results of a survey intended to answer the following questions: How much do Italian citizens know about nanotechnology? What is the benefit–risk perception of people? Do people trust science and scientists? Would people make use of nanotechnology-derived articles (in particular nanodrugs)? What do people think the government should do in terms of support, information, control and regulation? One of the main aims of our study was to gather information about the correlations between predisposing factors and benefit–risk perceptions of nanotechnology in Italy.

Despite the fact that Italy has profound cultural differences among northern, central, and southern regions, Rome can be considered as representative of Italy as a whole because it is the most populous city in the country and hosts people from all regions in Italy. The survey was organized as a questionnaire divided into six sections, each of them comprising a variable number of questions (23 in total). Interviewees were randomly sampled from trading centers in four different urban areas of Rome during weekdays and weekends. The questionnaires were distributed to the citizens sampled, who completed them while sitting around a table under a stand which had been assembled previously in the trading center. Here, we gathered the first results of the survey. Upon completing the questionnaire and interview, irrespective of the urban location of the trading center, the majority of interviewees chose to remain in the testing area to comment on the questionnaire and question us about nanotechnology and its state of development in Italy. The preliminary information we gathered by these face-to-face discussions suggested that Italian citizens do not feel themselves to be sufficiently informed about nanotechnology by the media, are seeking out more information, and believe that nanotechnology has more benefits than risks (several interviewees explicitly asked us if nanotechnology had any risks while completing the question 5.2.). Furthermore, several interviewees were skeptical about the work carried out by scientists because, in their opinion, scientists are enslaved by the economic and political interests of private companies (especially pharmaceutical) and by the government.

The results of the survey validated the impression we had from face-to-face discussions. In general, Italian citizens, although scarcely familiar with nanotechnology, have a positive attitude towards nanotechnology and the innovations it may bring, especially those related to health and medicine. Moreover, Italian citizens think that the government should invest, regulate, and control the development of nanotechnology in the medical field.

Results from the familiarity with nanotechnology section showed a picture already reported by surveys carried out in other countries (the US,[4,5,9,13–15] Canada,[14,15] Japan,[16] and Europe[3,8,20]), ie, that lay people have limited familiarity with nanotechnology. Italian citizens have heard about nanotechnology, mainly from television shows, but feel themselves just "a little" informed about it (Figure 2B). The low level of familiarity was also indicated by their minimal awareness of currently available consumables employing nanotechnology. The majority (80%) of the interviewees associated their awareness with use of electronic devices. A much lower percentage of subjects were aware that drugs and cosmetics are also modified by nanotechnology (so-called "nanodrugs" and "nanocosmetics"). However, although they were not aware of currently available nanodrugs and nanocosmetics, many people believed nanotechnology should primarily be used in fields related to health and medicine (question 2.4), where they foresaw the biggest benefits in their everyday life (question 5.1). This observation allows some conclusions. Italian information (mass) media should devote more space to describe better the presence of nanotechnology-derived

products currently used in everyday life. The majority of media presentations have been devoted to electronic devices (eg, cell phones, laptops, monitors), while very little effort has been made to explain to people that several nanoparticles (eg, titanium dioxide, zinc oxide, and silica nanoparticles) are already on the market, being used in personal care products (cosmetics and sunscreens), while the potential side effects of these products are still under debate among toxicologists.[21–23] Titanium dioxide nanoparticles are added to personal care products to block ultraviolet wavelengths of sunlight, which may cause skin aging and cancer.[21] However, these nanoparticles can eventually find their way into water sources (lakes and rivers) where people bathe, thereby entering micro-organisms (eg, bacteria essential for maintaining a healthy environment), animals, and even humans. Recent articles have shown that titanium dioxide nanoparticles elicited adverse effects in zebrafish (*Danio rerio*) and pregnancy complications in mice.[24,25] Evidence of toxicity has also been reported for other nanoparticles currently used in everyday life.[26–28] The same unique chemical and physical properties that make nanoparticles so attractive for biomedical applications may also be responsible for their often poorly understood side effects on cells and tissues. This scenario has increased the concern that a more rigorous assessment of the potential occupational, health, and environmental impact of innovative nanoparticles, along with more stringent regulations, would be necessary before introducing nanotechnology more broadly into everyday life.[29] Toxicologists have been working to highlight the pathways and mechanisms through which nanoparticles may exert their side effects. However, their findings (complementary to those of bioengineers regarding applications) have been reported mainly in scientific journals, which are far removed from lay (nonexpert) people. It appears necessary that mass media would devote much more space to inform lay people about both the potential applications (the benefits) and side effects (the risks) of nanotechnology-derived consumables, especially those entering the human body. Mass media must be objective while informing without aiming to transmit feelings, which would greatly influence people's affect and their benefit–risk perception.

Results from the social impact and trust in science sections revealed important aspects about the attitudinal predisposing factors of Italian citizens. People showed very high trust in science, but only moderate trust in scientists. Furthermore, they thought that nanotechnology may have a positive economic and occupational impact and that the government should invest in nanotechnology research (Figure 3A). It is not surprising that Italian citizens have a strong trust in science because Italy (together with other European countries) has a millenary scientific tradition. However, high trust in science did not translate into a similarly high trust in scientists. As revealed by the interviewees' comments, the antiscientist feeling was associated with an antigovernment attitude. This attitude is due to the fact that science and state are institutions, ideally perfect and aimed to guide people's lives, whereas scientists and parliamentarians are human beings, potentially inadequate to represent the institutions and/or readily enslaved by self-interest or to the profit of corporations (indeed, some interviewees stated that "scientists are just marionettes in the hands of parliamentarians and big pharmaceutical companies").

The results for perception of areas that might benefit from nanotechnology revealed that Italians adopt a consumerist attitude, judging a novel technology with regards to the benefits it may bring to individuals rather than to society. In particular, they perceived that health and electronics might gain higher benefits from nanotechnology than energy production, the environment and resource preservation (Figure 3B). This result differs from the study reported by Pidgeon et al, who described the benefit–risk perception of citizens from the US and the UK participating in workshops debating energy and health nanotechnologies.[11] People from those countries showed a greater tendency to discuss positively the potential applications of nanotechnology in energy production rather than in health and medicine. These differences might stem from different cultural assumptions and experiences in regard to health and health care institutions, energy efficiency, and independence from other countries. Workshop participants in the US and UK observed that applications for health would raise moral and ethical questions. Especially in the case of the UK, those considerations might have been (unfairly) drawn by analogies between nanotechnology and biotechnology, and memories of societal disasters (mad cow disease), harsh public disputes (about genetically modified organisms), and the failure of government regulation. During face-to-face discussions, Italian interviewees did not mention any recent failure of the Italian government in controlling new technologies, which in turn appears to correlate well with their perception that nanotechnology could bring health benefits. Allied to this, more than 70% of the interviewees affirmatively answered the question "Would you use a drug made of nanomaterials?" The general technological optimism and the absence of past failures to control innovative

technologies in Italy overwhelmed the concern about bodily incorporation of invisible particles predicted by past risk-perception studies.[19]

Interviewees were concerned about the environmental and societal implications (division among social classes and increases of public expenses) more than the health risks that nanotechnology may bring once it stably becomes part of everyday life (Figure 3B). The concern for societal risks deriving from use of nanotechnology was probably driven by the antigovernment feelings of the citizens, as displayed by their tendency to discuss misuse of novel technologies rather than technology per se. Furthermore, the limited familiarity with nanotechnology and the lack of awareness of already available potentially dangerous nanoparticles might have helped to steer the concern of the interviewees towards societal implications. However, an implied concern about health risks was noticed by the fact that Italian citizens would use nanotechnology-based consumables only if they clearly stated an absence of side effects, and they expressed the necessity to create a commission to control and regulate the development of nanomedicine (Figure 3C).

It is noteworthy that the public perception of societal risks deriving from nanotechnology has also been investigated by Priest et al.[13] The authors reported the evolution over time of benefit–risk perception of "nonexpert" US citizens and showed that the concern for nanotechnology-derived societal risks were on the rise and surpassed the concern about health and environmental issues. Moreover, US citizens perceived an equal need (and stably over time) for the creation of regulatory commissions to control the development of nanotechnology in areas related to human health and societal matters (public expenditure, benefit distribution, and privacy). Italian citizens perceived a greater need to create a commission to control the development of nanotechnology in areas related to health and environment with respect to those related to public expenditure and benefit distribution. Taken together, our data and those of Priest et al show a picture of the public risk perception that matches the one previously described for the public benefit perception, ie, Italians have a slightly greater consumerist attitude than Americans.

Finally, one of the main aims of this study was to understand the predisposing factors shaping the public benefit–risk perception. In particular, we investigated the role of four predisposing demographic (age, gender, education, and religion) factors and one heuristic (knowledge) factor. We first performed a Chi-square independence analysis, followed by an LDA and LRA to remove spurious correlations between predisposing factors (Figures 4 and 5). The results of these analyses show that gender, education, and knowledge (but not age and religion) influenced the perception of how nanotechnology will (positively or negatively) affect some areas of our everyday life in the next twenty years. It is noteworthy that increasing the level of education increased the concern about nanotechnology-associated health issues with respect to the societal implications (division among social classes). Highly educated people steered their concern toward health issues, while not decreasing their strong belief about the benefits that nanotechnology would bring to the medical field. The same trend (albeit not statistically significant) was observed with increasing (self-estimated) knowledge. However, in this survey, we considered self-estimated knowledge itself as a predisposing factor. Future work will investigate how increasing actual (rather than self-estimated) knowledge shapes the perception of the risks and benefits of nanotechnology.

Conclusion

Past risk perception studies and social experiences have clearly demonstrated that a technology that ignores citizens' perceptions of benefit–risk might jeopardize its public acceptability and hamper further development. Unlike other technologies, the public perception of nanotechnology has been described as "downstream," because surveys have been carried out before the occurrence of any nanotechnology-derived disasters. Italy has not yet experienced any technology-related failure that might have contributed to the shaping of its citizens' attitude toward the nanotechnology benefit–risk ratio. Indeed, the general picture that emerges from this survey is that Italian citizens, despite limited familiarity with nanotechnology, are optimistic about the applications of nanotechnology, in particular nanomedicine. Furthermore, the high regard for nanomedicine was allied to the perception of risks not associated with specific adverse health events, but rather to the perceived inability of politicians to manage and regulate novel technologies. It is impossible to establish the robustness of the optimism of Italian citizens toward nanomedicine, and forecast their perception after they increase their actual knowledge or encounter a health disaster.

Our social survey is only the starting point in understanding the forces driving public affect. Italian citizens showed optimism towards nanomedicine, although they were hardly aware of currently available nanodrugs and nanocosmetics, the biocompatibility and toxicity of which

is often not well understood and still under investigation. However, if public optimism justifies the increase in scientific effort and funding for nanomedicine, it also obliges toxicologists, politicians, journalists, entrepreneurs, and policymakers to be more responsible in the dialog they pursue with the public.

Acknowledgments

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Disclosure

The authors declare no conflicts of interest in relation to this work.

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Appendix

Survey questionnaire

1. Demographic characteristics
   - 1.1. Age: …
   - 1.2. Gender:
     - □ M
     - □ F
   - 1.3. Education:
     - □ Elementary school
     - □ Middle school
     - □ High school
     - □ Degree
   - 1.4. What is your religion? …
2. Familiarity with nanotechnology
   - 2.1. Have you ever heard about nanotechnology?
     - □ Yes
     - □ No
   - 2.2. If you answered Yes to question 2.1, where have you heard about nanotechnology?
     - □ TV
     - □ Radio
     - □ Newspapers
     - □ Internet
     - □ Other
   - 2.3. If you answered Yes to question 2.1, how much do you know about nanotechnology?
     - □ A little
     - □ Moderate
     - □ Very much
   - 2.4. Where may nanotechnology have the biggest use?
     - □ Electronics
     - □ Medicine
     - □ Engineering
     - □ Mechanics
     - □ Other
   - 2.5. Are you aware of using nanotechnology-derived articles of consumption?
     - □ Yes
     - □ No
   - 2.6. If you answered YES to question 2.5, give some examples. …
3. Trust in science
   - 3.1. On a scale from 1 to 10, how much do you think science is important in the society?
     …
   - 3.2. On a scale from 1 to 10, how much do you believe the information (about risks and benefits) furnished by scientists?
4. Social impact
   - 4.1. Do you think that nanotechnology could have an economic and occupational impact?
     - □ Yes
     - □ No
     - □ Not sure
   - 4.2. Do you think the government should promote research about nanotechnology?
     - □ Yes
     - □ No
     - □ Not sure
5. Benefits and risks
   - 5.1. In which area(s) among those described below will nanotechnology bring the highest benefits in the next two decades?
     - □ Health and medicine
     - □ Agriculture
     - □ New materials
     - □ Electronics
     - □ Environment
     - □ Resource preservation
     - □ Energy production
   - 5.2. In which area(s) among those described below will nanotechnology be a risk in the next two decades?
     - □ Human health
     - □ Animal health
     - □ Environmental pollution
     - □ Increase of public expenses
     - □ Division among social classes
     - □ Economic loss
6. Benefit–risk perception
   - 6.1. Would you like it if the presence of nanomaterials were explicitly stated on articles of consumption?
     - □ Yes
     - □ No
     - □ Not sure
   - 6.2. Would you buy an article of consumption made of nanomaterials?
     - □ Yes always
     - □ Yes but only for non-alimentary articles
     - □ Yes but only if it is stated that the article does not elicit side effects
     - □ Never
   - 6.3. Would you use a drug made of nanomaterials?
     - □ Yes
     - □ No
     - □ Not sure

6.4. Do you think it is important to create a commission of control to regulate the use of nanotechnology?
- □ Yes
- □ No
- □ Not sure

6.5. If you answered Yes to question 6.4., in which fields?
- □ Health
- □ Environment pollution
- □ Increase of public expenses
- □ Benefit distribution

6.6. Do you think you are sufficiently informed by media (television, radio, newspapers, Internet) to evaluate what nanotechnology is and the risks and benefits of technological innovations?
- □ Yes
- □ No
- □ Not sure