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Should Governments Fund Basic Science? Evidence from a Willingness-to-pay Experiment in Five Universities

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Abstract
Tax-payers are usually the ultimate funders of large-scale research infrastructures (RIs), but the expected discoveries of such projects often do not have any known use-value. By interviewing 1,022 undergraduates, we study the drivers of preferences for paying for basic research, which are still little known. We focus on the LHC at CERN, where the Higgs boson was discovered. Income, awareness, and positive attitudes towards science drive a positive willingness-to-pay for science. Students in social sciences and the humanities are willing to contribute to scientific curricula at least as much as their peers. Findings offer support to government funding of basic research as a public good.

Keywords: Research infrastructures, Basic science, Non-Use Value, Willingness-to-pay, Large Hadron Collider, CERN, Particle Physics

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1 Introduction

How justified is it that taxpayers support research that has no use-value to them? In the past decades, an increasing number of governments and institutions have supported basic research defined by (OECD 2002) as 'experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view'. In the near future, several ambitious projects are at stake (ESFRI 2016). The European Organization for Nuclear Research (CERN) in Geneva has achieved the leadership in particle physics thanks to the Large Hadron Collider (LHC) and the announcement of the Higgs boson discovery in 2012. Recently, CERN has also launched a study of the Future Circular Collider (FCC), laying the foundations for the post-LHC era (Banks 2014; Reich 2013). Other countries, including Japan and China, are planning large-scale scientific ventures for the next decades (e.g. the Circular Electron Positron Collider programme).

These Big Science projects are very costly and lawmakers may be reluctant to fund them. In 1993, US Congress abandoned the SSC project because of an increase in the estimated costs from 4.4 billion USD to 12 billion USD (Baggott 2012; Giudice 2010). The current value until 2025 of the LHC and experiment costs (excluding scientific personnel in more than one hundred associated universities among the collaborations) is around 13.5 billion EUR (Florio et al. 2016). Is it worth it for taxpayers to fund such projects? What drives people to pay for large-scale RIs? The question is particularly intriguing when basic research is considered, since its above-mentioned definition acknowledges that it still has no visible utility for the average taxpayer.

In the traditional perspective of welfare economics, the value of a good arises from its use, or utility. Nevertheless, since the Sixties, environmental economists have been arguing that there may be a value arising from its non-use, including the pure existence of the good itself (Krutilla 1967; Weisbrod 1964). Bateman et al. (2002) classify non-use value into three main categories: bequest value, option value and existence value; in some cases, the notion of quasi option value is added to the list (Boardman et al. 2001). The option value arises when it is possible to predict some use of the good in the future although there is still no use at the present time. If the future use of the good is still not known or is unpredictable, and if there is irreversibility, then the notion of a quasi-option value may be proposed (Johansson and Kristrom 2015).[1] Unlike bequest (or altruism), option and quasi option values, existence value originates from the utility that arises from the mere perception of the existence of the good, even in absence of any expected or unpredictable use (Brun 2002; Walsh et al. 1984). Several studies worldwide provide empirical estimations of the existence value of environmental goods (Amirnejad et al. 2006; White and Lovett 1999; Echevverria et al. 1995; Heafele et al. 1991). Throughout the last twenty years, the concept of existence value has been transferred to cultural economics (Packer 2008; Alberini and Longo 2006; Frey 2003; Hansen 1997; Pagiola 1996).

Following this previous literature, (Florio and Sirtori 2016) and (Florio et al. 2016) suggest that the notion of existence or intrinsic value can be extended to RIs, and, in general, to basic science. Specifically, since there may be a public preference for 'curiosity-driven' new knowledge per se (Archibugi and Filippetti 2015), the existence value of RIs should arise from the pleasure (or utility) of knowing that something may be discovered, hence its existence is revealed, even if there is no predictable use of it. If so, there is an analogy between scientific discoveries and environmental goods and the only difference is that natural environments are something that are known to exist and that may be endangered, while a discovery reveals something that already exists in nature, but was previously unknown.

[1] Actually, over the years, the notion of option value in economics has taken different meanings. For instance, according to Dixit and Pindyck (1994) a (real) option value arises when a firm makes an irreversible investment under conditions of uncertainty. The irreversibility "kills" alternative options to invest and the firm cannot disinvest should market circumstances change unfavourably. This definition is closely related to the notion of quasi-option value, the difference being that option value includes a pure postponement value for an investment.

The use and non-use value of RIs may justify, to a certain extent, governments' support of basic research, but little is known about the intensity of public preferences in this area. An initial analysis of public preferences for large RIs is essential to ensure successful strategies to secure political support and the social acceptance of such projects.

Are people actually willing to pay for curiosity-driven Big Science? What are the rationales behind this preference? This study was motivated by the need to provide some possible answers to these questions by focusing on the LHC, the world's largest and most powerful particle accelerator, built at CERN from 1994 to 2008.[2] After the discovery of a new particle consistent with the Higgs boson and predicted by the Standard Model of particle and forces,[3] in the near future new possible discoveries are expected to shed light on the current theory of fundamental interactions and on the puzzle about the origin of the universe.

Since its construction phase, the LHC has attracted great interest from the general public. From 2004 (when the LHC was opened to visitors) to 2013, 418,200 people visited the LHC, reaching a peak of about 100,000 visits per year in the aftermath of the announcement of the Higgs boson discovery (Florio et al. 2016). Travelling exhibitions related to the LHC have attracted 344,000 visitors worldwide up to 2013. In the same period, the users of LHC-related social media (YouTube, Twitter, Facebook and Google+) amounted to around 2,010,000, while the number of CERN-LHC website visits surpassed 37 million. These figures are expected to further increase in the near future suggesting that the LHC has a cultural impact on the general public that should be analysed separately from its scientific impact.[4]

Focusing on discovery potential at the LHC, our paper examines the interplay between basic science and its perception by a survey involving a sample of young European citizens outside the scientific community. The main difference between our survey and other qualitative social attitude surveys about science is that we introduce questions about the willingness to financially contribute to a specific research infrastructure. In fact, the general public indirectly supports science through taxation and CERN is entirely funded by its Member States, but little is known about what drives preferences for funding large scale RIs. Are governments misinterpreting the preferences of voters? Two of our questions investigate the willingness to pay (hereafter, WTP) a proposed amount of money and we study the distribution of the answers. In this pilot study, we are mainly interested in singling out the factors affecting individual preferences (socio-economic and cultural characteristics) for research at the LHC, that is for a scientific project providing discovery as a pure public good (Archibugi and Filippetti 2015; Stiglitz 1999). In contrast, a robust estimation of actual taxpayers' WTP for particle physics LHC research is beyond the scope of this study.

We provide insight into both research and policy. In terms of research, by using a survey addressed to European undergraduate students (i.e. to the taxpayers of tomorrow), this study investigates the public's perceptions of what fundamental science is and what it means to the most educated segment of the population. Meanwhile, from a policy viewpoint, this study takes a step forward in suggesting that surveys providing quantitative information on preferences in this area (as now well established in environmental economics) are feasible. This, in the future, could help policy-makers and stakeholders make appropriate decisions for developing the next generation of large scale RIs.

[2] Collisions between hadrons (and ions) are detected to find answers to many issues left unsolved by the Standard Model of particles and forces, such as the origin of particles' mass, a coherent explanation of the interactions among the fundamental forces of the universe, and the phenomena responsible for dark matter. The LHC should also help to investigate some issues related to the portion of matter and anti-matter in the universe. For further details see http://cds.cern.ch/record/1165534/files/CERN-Brochure-2009-003-Eng.pdf

[3] The Higgs mechanism may shed light on the mass of particles and may explain why some particles are very heavy while others have no mass at all. According to the Higgs mechanism, the whole of space is filled with a Higgs field, and the way in which particles interact with this field determines their specific masses. The Higgs boson is one of the new particles predicted by the Higgs mechanism.

[4] The cited figures are our elaborations on data in Florio et al. (2016). For more on the outreach and the cultural impact of particle physics research at CERN see Kahle et al. (2016).

The paper is structured as follows. Section 2 briefly summarizes the relevant literature. In Section 3, we discuss our methodology and the survey. Data and descriptive statistics are presented in Section 4, while Section 5 reports the results. Section 6 concludes by discussing results, caveats, and providing suggestions for further exploration in this new field of research.

2 Relevant literature

The literature on people's perceptions, attitude and interest in science, research and innovation focus on variables that mainly belong to one of three groups: demography, financial resources and cultural values such as the attitude towards voluntary donation and awareness about ongoing scientific challenges and discoveries (Potvin and Hasni 2014; Kim et al. 2014; European Commission 2014; 2010). Demographic variables constitute the personal characteristics and they are presumed to affect behavioral patterns (Frank et al. 2015; de Jonge 2015; European Commission 2014). Financial resources measure the capability to contribute to a public good and are thus considered an essential prerequisite to be willing to pay (Ubilava et al. 2010; McClelland and Brooks 2004). Personal cultural values, as well as the act of giving *per se*, are considered important drivers of the willingness to contribute because they represent motivational forces to pursue goals and intentions such as those that are relevant for the provision of public goods. Since some people may derive moral satisfaction or a "warm glow" from the act of giving, these values may be seen as a perfectly legitimate source of the social attitude of being willing to pay (Ubilava et al. 2010; Kahneman and Knetsch 1992).[5] Against this theoretical backdrop, our research focuses on demographic characteristics, financial situation and personal values and attitudes as possible determinants of preferences for potential scientific discoveries at the LHC.

Demographic characteristics. We explore the effect of sex, age, education field, household composition and country of origin. Literature on science and technology tends to hypothesize that interest in this topic is greater for men than women and for younger rather than older people (European commission 2014; 2010; Desy et al. 2011). One reason for the gender gap is that there is a general lack of integration of women in scientific fields (European Commission 2010; Steele et el. 2002; Okeke 1986), particularly in physics-related matters (Drechsel 2011; Dawson 2000; Jones et al. 2000). Moreover, men seem to have slightly more trust in science than women (de Jonge 2015). Regarding age, many studies suggest that there is a decline of positive interest, motivation and attitude towards science and technology with age (see Potvin and Hasni 2014 for a review). This is because younger people who are interested in science have better chances of finding a job and/or because science prepares the younger generation to act as well-informed citizens (European Commission 2010). As a result, we expected the social attitude towards the discovery potential at the LHC, as measured by WTP, to be lower for women and older people. Similar results are reported in studies on WTP for technology and innovativeness (Frank et al. 2015; Kwak and Yoo 2012).

The link between interest, motivation and attitude towards science and technology and the choice to pursue studies in science and technology has, not surprisingly, been found to be positive (Potvin and Hasni 2014; Cheung 2009; Francis and Greer 2001). From our research perspective, this means that the tendency to be willing to contribute to scientific research at the LHC should be greater for students enrolled in scientific faculties than students in social sciences and humanities (hereafter, SSH) related faculties.

The impact of household size, i.e. the number of household members, on WTP for public goods has been investigated in many studies (Browning et al., 2014; Johannesson et al. 1996). They yield results where the stated WTP decreases with the household size: as family size increases, budgets tighten and WTP falls. However, contrary to this hypothesis, (Ahlheim 2013) demonstrates that the topic remains rather controversial because when projects bringing social welfare improvements are evaluated one would expect the preferences, as measured by WTP, for such projects to increase with the household size, since in households with many people more people will benefit from that project than in single-person households.

[5] It should be said that some economists question the inclusion of these kinds of values in a cost-benefits analysis (e.g. Milgrom 1993).

Analysing public perceptions, interest and motivation in science is the focus of many papers (Wang and Berlin 2010; Iqbal et al. 2008; Murphy et al. 2006; NBS 1977). Authors often connect them to cultural and local differences that are not easy to identify, preventing a unified view. This point is particularly relevant in this study because respondents' willingness to contribute to scientific discovery at LHC may depend on the extent to which a country has contributed to the funding of the LHC or on the country's relation with CERN. For instance, Italy is the most represented country at CERN, with more than 1,500 scientists.[6] In order to capture such country heterogeneity and contextual factors, in our empirical exercise we always check for country-fixed effects (Kim et al. 2014).

Financial situation. Higher income people or families are, on average, willing to pay higher premiums for public goods. This is a rather standard result in economics (Browning et al., 2014). Economics of science, technology and consumer innovativeness shows, on average, a positive correlation as well (Frank et al. 2015; Potvin and Hasni 2014). One concern that is related to our study is that, since we surveyed undergraduates, most of them might not earn a personal income. Thus, one may ask where their virtual contribution to discoveries come from. In order to overcome this potential bias, we inquired into both personal and family income and discuss the effect of both sources of income in the empirical analysis.

Personal values and attitudes. We inquired about knowledge of RIs, awareness of the LHC and the Higgs boson, interest in research, importance of funding RIs, and finally having visited CERN. Many articles refer to the constructs of 'interest' and 'motivation' that drive/guide behaviour and preferences towards an object of interest at the expense of others (Autio et al. 2011; Weinberg et al. 2011; Baram-Tsabari et al. 2010; Lau and Roeser 2008). The main references supporting the use of the interest construct are Krapp and Hidi's work, which claimed the positive relationship between individuals and the object of interest (Uitto et al. 2006). Moreover, at least since Arrow (1951), the modern theory of social choice has emphasised that individual preferences reflect selfish interest or moral satisfaction and judgement: "The individual may order all social states by whatever standards he deems relevant". Therefore, in addition to demographic and financial variables, we consider the above personal values and attitudes as potentially important determinants for the formation of WTP for scientific discoveries. Regarding visits to CERN, the literature suggests a positive link between interest, motivation and attitude towards science and experiential learning, and science and technology museums or centres (Chen and Howard 2010; Bozdogan and Yalcin 2009; Zoldosova and Prokop 2006).

3 Methodology and analytical framework

Drawing from the methodological insights of this literature, we developed a survey addressed to undergraduates with the aim of detecting the explanatory variables, conditional to our sample, that potentially affect individuals' social attitudes, as measured by WTP, for the LHC as a provider of scientific discovery. A pilot survey was initially conducted at the University of Milan by interviewing 61 students in order to calibrate the structure, the number of questions and the duration of the interview, as well as to verify that the questionnaire was readable and clear so as to reduce the respondents' rejection rate.

Given the peculiarities of the public good under evaluation, before starting the interview, a brief description of the LHC was provided to interviewees, which consisted of a shortened version of the Wikipedia entry "Large Hadron Collider" and five photos. The questionnaire was structured into three sections. The first section investigated background knowledge and broad awareness of respondents in relation to RIs (i.e. personal values and attitudes). Open-ended and five-point Likert scale questions were added to binary-choice questions to further detect the interviewees' preferences and interest towards

[6] This figure refers to CERN users. See, for further details, http://international-relations.web.cern.ch/stakeholder-relations/states/Italy.
Moreover, at the end of 2014, the Italian physicist Fabiola Gianotti was elected Director-General of CERN and her mandate began on January 1, 2016.

research. The second section focused on the LHC and included our WTP questions (see below). The final section of the questionnaire requested personal information and, specifically, asked questions about the respondents' demography and financial situation. In particular, it inquired into age, sex, country of residence, university studies, income, and household composition.

Social attitudes, as measured by WTP, were inquired into as follows. First, a general question detected students' willingness to pay for the research activity at the LHC, without mentioning any bid. Afterwards, two follow-up questions were submitted to respondents. The first one asked respondents about their willingness to offer a single lump-sum payment amounting to EUR 30 and provided three possible alternative answers: '*yes*', '*no*' and '*do not know*'. The amount of EUR 30 comes from Florio et al. (2016), who carried out a review of studies worldwide on the existence value of public goods, particularly environmental, health and cultural goods. The benefit of offering a '*do not know*' response, in addition to the '*yes*' and '*no*' options, is that uncertain survey respondents are not forced to construct WTP when answering the questions. Moreover, in order to avoid anchoring problems to the bid of EUR 30 and investigate to what extent positive WTP exists below that threshold, the second follow up question asked respondents' WTP in the form of an annual fixed contribution of EUR 0, EUR 0.5, EUR 1 or EUR 2.

In any case, respondents were also asked to explain their choice by filling in an open-ended question as proof of his/her sincerity and to identify "protest bids"; i.e. investigate the reason why people are not willing to pay for the good.

Our research question aimed at examining the explanatory variables affecting social attitudes, as measured by WTP for discovery potential at the LHC. To this end, we adopted a standard multinomial logit (MNL) model (Maddala 1994) when WTP was asked as a single lump-sum payment, and an ordered logistic model (Greene, 2012) when the dependent variable was WTP expressed as an annual fixed contribution.

In the multinomial model, we have N independent observations, where the dependent variable of interest, WTP_i $(i = 0,1, \dots, N)$ is a discrete unordered variable that takes on M categories $(m = 1,2, \dots, M)$. One category of the dependent variable is designated as the reference category. The probability of membership in other categories is compared to the probability of membership in the reference category. For a dependent variable with M categories, the model requires the calculation of $M - 1$ independent binary logistic regression models, one of each category related to the reference one, to describe the relationship between the dependent variable and the independent variables.

In our case, WTP took on $M = 3$ categories: '*no*', '*do not know*', '*yes*'. Therefore, if the '*no*' category is the reference, then for $m =$ '*yes*', '*do not know*', we had:

$$Pr(WTP_i = yes) = \alpha_{yes} + \sum_{k=1}^{K} \beta_{yes,k} X_{i,k} \qquad (1)$$

$$Pr(WTP_i = do\ not\ know) = \alpha_{do\ not\ know} + \sum_{k=1}^{K} \beta_{do\ not\ know,k} X_{i,k} \qquad (2)$$

where α was the constant of the model, β was the vector of regression coefficients and the index $k = 1, \dots, K$ represented the number of independent variables entering into the model. In the MNL model there were $M - 1$ predicted log odds which featured separate sets of regression coefficients, one for each possible category. Equations (1) and (2) revealed the probability of answering '*yes*' and '*do not know*' with respect to '*no*' respectively as a function of the independent variables when no bid was offered. We defined them 'participation equations' and the results of such an estimation are presented in Table 5.

When the bid was introduced, the model indicated the probability of answering '*yes*' and '*do not know*' with respect to '*no*' respectively as a function of the independent variables, given the proposed bid of EUR 30. Specifically:

$$Pr(WTP_i = yes | EUR\ 30) = \alpha^{I}_{yes} + \sum_{k=1}^{K} \beta^{I}_{yes,k} X_{i,k} \qquad (3)$$

$$Pr(WTP_i = do\ not\ know|EUR\ 30) = \alpha^{I}{}_{do\ not\ know} + \sum_{k=1}^{K} \beta^{I}{}_{do\ not\ know,k} X_{i,k} \quad (4)$$

where $\alpha \neq \alpha^{I}$ and $\beta \neq \beta^{I}$. We defined equations (3) and (4) 'level equations' and the results of such an estimation are presented in Table 6.

The estimation of a MNL model requires testing whether the assumption of Independence of Irrelevant Alternatives (IIA) holds. This assumption states that the odds of preferring one category over another do not depend on the presence or absence of other "irrelevant" alternatives: the relative probabilities of choosing '*yes*', '*do not know*' or '*no*' do not change if an additional possibility is added. This enables the choice of M alternatives to be modelled as a set of $M-1$ independent binary choices. Empirically, the IIA assumption is checked by comparing the estimated parameters of alternative estimation strategies.[7] The p-values associated with the resulting test statistics are reported in the last rows of Tables 5 for the binomial logit described by equations 1 and 2 and in Table 6 for the binomial logit described by equations 3 and 4. Not statistically significant values of the Hausman test indicate that the IIA assumption has not been violated.

An ordered logistic model is applied when the willingness to contribute was asked in the form of yearly payments since it represents a dependent count variable taking on values from j = 0 to J = 2 and therefore can be treated as an ordinal variable.[8] The conditional distribution of the respondents' answers across the proposed bids is given by equation (5):

$$\Pr(WTP_i = j) = \Lambda(\tau_j - X_{ik}\beta^{II}) - \Lambda(\tau_{j-1} - X_{ki}\beta^{II}) \quad (5)$$

where $\Lambda(.)$ denotes the logistic distribution function and τ_j are unknown thresholds (cut-points) to be estimated.

4 Data and descriptive statistics

The survey was conducted between June 2014 and March 2015. 1,022 valid questionnaires were filled in by students coming from five European universities located in four countries: University of A Coruña (Spain), University of Exeter (UK), University of Milan (Italy), University Paris 7- Denis Diderot and Sciences Po University (France). A pilot survey was conducted at the University of Milan in order to calibrate the structure, the number of questions and the duration of the interview as well as to verify that the questionnaire was readable and clear so as to reduce the respondents' rejection rate. The pilot test involved a total of 61 students.[9] The questionnaire (available in Annex) was originally submitted in Italian during the pilot test and then translated into English, French and Spanish by a company specialised in market research.

[7] The efficient estimation of parameters resulting from MNL requires that all pairs be estimated simultaneously, which imposes certain logical constraints among parameters; in contrast, consistent but inefficient estimates can be obtained by estimating a series of binary logits. In order to test the IIA assumption, we conducted two Hausman tests. In the first one, the MNL results were compared with those from a binomial logit model between the '*yes*' and '*no*' samples. In the second one, the MNL results were compared with those from a binomial logit between the '*do not know*' and '*no*' samples. If two alternatives are more similar to one another than the third alternative, as might be supposed, for example, and if individuals answering '*do not know*' and '*no*' behave similarly, we expected the IIA test to reveal such similarities. This procedure was carried out for both the participation and the level equations.

[8] As demonstrated by Harris and Zhao (2007), traditional ordered logit models (like those we applied) have limited capacity in explaining zero observations. In these cases, the authors suggest using a zero-inflated ordered logit model by applying a double combination of a split logit model and an ordered logit model (if some conditions concerning the variance-covariance-structure of the bivariate distribution of the error term hold). In the first step a logit model, in which the dependent variable takes on 'zero' value for students who chose EUR 0 (they are not willing to pay) and 'one' for the remaining sample (i.e. people who are willing to pay EUR 0.5, EUR 1 or EUR 2) should be estimated. In the second step, an ordered logit model discriminating between EUR 0.5, EUR 1 and EUR 2 should be implemented. We checked the robustness of our results by applying both the standard ordered logit, as reported in Table 7, and the zero-inflated ordered logit as suggested by Harris and Zhao (2007), whose results are available upon request. No significant differences emerged between these two estimation methods regarding the determinants of WTP.

9 For more details on the pilot test carried out at the University of Milan see https://www.csilmilano.com/PDF/News/2014/CERN_LHC.pdf

Interviews were face-to-face and required 20-30 minutes. They were carried out by hired students, who were instructed in order to minimize possible respondents' perceptions related to the promotion of the interests of any particular party (e.g. CERN, University of Milan) and reduce suspicions related to highly sensitive information, e.g. income (Bohm, 1972).

The descriptive statistics of the variables in relation to the profile of students in terms of demographic features and respective codes are presented in Table 1. The sample comprises 420 (41%) students from Italy, and about 200 (20%) from Spain, France and the UK each. They were enrolled in more than 30 different university degrees: 655 (65.1%) of the respondents were enrolled in social science and humanities and 352 (34.9%) in scientific degrees; 578 (57%) of the respondents were female and 86% (857 students) were between 19 and 25 years of age, while the remaining share was more than 26 years old. Most students belonged to a family with 3 to 5 members (774, corresponding to 75.7% of the sample), 174 (17%) to a family with 1 or 2 members and only a small share (7.2%) to a family composed of more than 5 people.

Table 1. Descriptive statistics of demographic characteristics

Variable	Code	Number	Percent
C0.1 Country	1 = Italy	420	41.0
	2 = Spain	202	19.8
	3 = France	200	19.6
	4 = UK	200	19.6
C0.2 Education[a]	0 = Scientific[c]	352	34.9
	1 = SSH[b]	655	65.1
C1 Age	1 = 19-25	875	85.6
	2 = 26-30	94	9.2
	3 = 31-35	33	3.2
	4 > 35	20	2.0
C2 Gender	0 = Male	444	43.4
	1= Female	578	56.6
C8 Household Composition	1 = 1-2	174	17.0
	2 = 3-5	774	75.7
	3 > 5	74	7.2

Question C0.1: Country of residence
Question C0.2: Faculty
Question C1: Age
Question C2: Sex
Question C8: Household composition (including parents, brothers/sisters)
[a] 15 observations are missing
[b]SSH include economics, finance, marketing and management, political sciences, sociology, semiology, anthropology, humanitarian sciences, sport sciences, urban studies, education, law, foreign languages, international relations, literature, philosophy, history, geography, cultural assets, communication and media, theology, cryptography, musicology
[c]Scientific sciences include medicine, pharmacy, chemistry biology, mathematics, physics, engineering, architecture, mechanics, ICT.

Regarding income, respondents were asked both on the availability of personal income and on the amount of the family income. The joint distribution of income variables is reported in Table 2. The numbers in parentheses denote the distribution function of the single variable. Only 304 (30%) students earn his/her own income. The largest share (70%) was financially supported by his/her family. Most households fell in the income category ranging from EUR 1,000 to 3,000 per month (478 respondents, representing 47% of the sample), followed by a 23% share with a monthly income ranging from EUR

3,000 to 5,000. 19% and 11% of the respondents fell in the lowest (less than EUR 1,000) and highest (more than EUR 5,000) family-income categories respectively. The Spearman correlation coefficient between the two variables was negative, meaning that students who earned his/her own income came from families with a low-medium income. Table 2 shows that 65.2% of the respondents with a personal income belonged to families with less than EUR 3,000 per month. In the following analysis, it was decided to use family income (Question C6) rather than the availability of their own income (Question C7) as an independent variable. This approach was based on the fact that only 30% of the respondents earned their own income; therefore it was very likely that their decision-making process about willingness to pay was highly influenced by family budget constraints.

Table 2. Descriptive statistics of income variables

C6 Family monthly income (EUR) [a]		C7 Respondent's availability income	
		0=No 718 (70.3%)	1=Yes 304 (29.7%)
1= < 1,000	189 (18.5%)	15.9%	25.4%
2= 1,000 - 3,000	478 (46.8%)	50.3%	39.8%
3= 3,000 - 5,000	231 (22.6%)	23.1%	22.4%
4= > 5,000	113 (11.1%)	10.7%	12.4%

Question C6: In which of the following brackets does your family monthly net income fall?
Question C7: Do you have your own personal income?
[a]11 observations are missing

Personal cultural values and attitudes are presented in Table 3. Out of 1,022 respondents, 554 (54.2%) were aware of what a research infrastructure is and 480, representing 53% of the whole sample, associated it with a particle accelerator when asked to identify a RI among some alternatives (see Question A2, Table 3). 845 (83%) interviewees stated that they had an interest in scientific discoveries, and more in general in scientific research, and 85% recognised that funding RIs is at least important. The LHC was known by 535 (52.3%) interviewees. Their source of information mainly consisted in internet, magazines and TV (62.4%). 117 (21.9%) students declared that they had heard about the LHC at university or through cultural activities such as seminars and meetings, while 83 (15.7%) heard of it from friends. The Higgs boson was known by 620 (60.7%) of the respondents and 97 (9.3%) had already visited CERN.

Table 3. Attitude towards science and awareness of the research at LHC related variables

Variable	Code	Number	Percent
A1 Knowing what a RI is	0 = No	468	45.8
	1 = Yes	554	54.2
A2 Particle accelerator[a]	1=Particle accelerator	480	53.0
	0 = Other	542	47.0
A4 Interest in research	0 = No	177	17.3
	1 = Yes	845	82.7
A6 Importance of funding RI	1= Useless	4	0.4
	2 = Insignificant	13	1.3
	3= Important Enough	142	13.9
	4 = Important	473	46.3
	5 = Fundamental	390	38.2
B1 Having heard about the LHC	0 = No	487	47.7
	1 = Yes	535	52.3
B2 Source of information about the LHC	University	117	21.9
	TV	119	22.3

	Magazines	86	16.1
	Internet	130	24.0
	Friends	83	15.7
B3 Having heard about the Higgs boson	0 = No	402	39.3
	1 = Yes	620	60.7
B5 Having visited CERN	0 = No	927	90.7
	1 = Yes	97	9.3

Question A1: Do you know what a research infrastructure is?

Question A2: In your opinion, which of the following is a research infrastructure? telescope; instrument of data collection and archive; data elaboration software; particle accelerator; library; computer; astronomical observatory; planetarium. This was a multiple-answer question.

Question A4: Are you interested in scientific discoveries and in research activities in general?

Question A6: how do you rate the importance of funding research infrastructures?

Question B1: Did you hear about the LHC before this questionnaire?

Question B2: If yes, please indicate your source of information.

Question B3: Did you ever hear of the"Higgs boson"?

Question B5: Have you ever been to CERN?

[a]Elaboration on B1 = Yes

Respondents were asked about their willingness to contribute to the research activity at the LHC by firstly proposing to them a general question without mentioning any bid. 191 (19%) respondents were willing to financially support the LHC, 335 (33%) explicitly declared they would not be willing to pay, and the remaining share said that they did not know.

Afterwards, two questions integrating, respectively, two different payment systems, were submitted. The first question was: "By 2015, would you be willing to offer an economic contribution equal to EUR 30, renouncing other personal expenses?" with the offered answers being '*yes*', '*no*' and 'd*o not know*'. The survey revealed that the '*yes*' percentage remained quite stable (15%), while '*no*' responses increase to 500 (49%). When looking at the second question related to lower annual payments, the share of respondents who would have been willing to contribute EUR 0.5, EUR 1 and EUR 2 were respectively 83 (8%), 229 (22%) and 438 (43%) summing to 73% of the respondents who would have paid. The remaining 27% (274 students) would have been willing to pay EUR 0.

These figures suggest that people react differently to different payment proposals and in the next section we investigate the individual characteristics affecting such a decision-making process in depth.

In both scenarios, five protest answers were identified. Three respondents said '*no*' because they thought national governments should be in charge of funding RIs; while two respondents were against the allocation of resources for the LHC in a time of economic crisis. Protest answers represented a negligible share (2%) and they had no effects on our findings. The most quoted motivations behind not being willing to pay were the non-affordability of the bid offered, the low interest in scientific discoveries and the lack of sufficient information about the LHC.

Table 4 analyses the overall correlation between the variables presented above. As the variables are expressed in ordinal intervals, we used the Spearman rank correlation matrix. Table 4 shows that the variables expressing attitude towards science and awareness about fundamental research at the LHC (A1, A2, A4, A6, B1, B3, B5) are significantly correlated with each other. Being so, we carried out a principal component analysis (PCA), which was applied to this set of independent variables in order to obtain new continuous variables (factor scores), which were orthogonal to each other. In the later multivariate analysis, we employed alternative models including both factor scores as independent regressors and original variables. The PCA revealed two factor scores: the first one was positively associated with variables A2, B1, B3, B5; the second one with variables A4 and A6. Consequently, we labelled the first component "Awareness about LHC research" and the second one "Attitude towards science". PCA results were based on the extraction of components with eigenvalues greater than one, the matrix of loadings was simplified by using Varimax rotation and the resulting principal component loadings were used to interpret the results.

Table 4. Spearman's Rank Correlations

	B8	B10	C0.2	C1	C2	C6	C8	A1	A2	A4	A6	B1	B3	B5
B8 WTP	1													
B10 WTP EUR 30Fixed	0.45*	1												
C0.2 Education (SSH)	0.01	0.01	1											
C1 Age	-0.03	-0.01	0.03	1										
C2 Gender (Female)	0.07*	0.07*	-0.005	-0.04	1									
C6 Family monthly income	0.07*	0.09*	0.08*	-0.006	0.04	1								
C8 Household composition	0.06	0.05	-0.04	-0.03	0.01	0.08*	1							
A1 Knowing what a RI is	0.03	0.04	0.06	-0.07*	0.09*	0.02	0.04	1						
A2 Particle accelerator	-0.01	0.03	-0.11*	0.05*	-0.19*	-0.05	0.01	-0.27*	1					
A4 Interest in research	-0.001	0.09*	-0.13*	0.08*	-0.01	0.04	-0.04	-0.06	0.07*	1				
A6 Importance of funding RI	0.004	0.002	-0.04	0.04	0.002	0.02	-0.07*	-0.15*	0.13*	0.13*	1			
B1 Having heard about LHC	-0.004	0.02	-0.15*	0.005	-0.21*	0.05	0.003	-0.07*	0.24*	0.10*	0.15*	1		
B3 Having heard about Higgs boson	0.04	0.06*	-0.10*	-0.02	-020*	0.07*	0.02	-0.08*	0.27*	0.16*	0.10*	0.46*	1	
B5 Having visited the CERN	0.07*	0.02	-0.08*	0.01	-0.02	0.004	0.003	0.04	0.03	0.10*	0.05	0.20*	0.16*	1

* Significant at 5% level

5 Results

Table 5 reports the multinomial logit estimates of participation equations (1) and (2). The determinants of being willing to pay are investigated through three different models. In Specification 1, we examine the impact of demographic and financial features while leaving out variables expressing personal values and attitudes. The latter were added in Specification 2, where their impact is analysed by looking at the original set of variables.[10] In Specification 3, we make use of the factor scores resulting from PCA rather than using the original variables. Standard errors are reported in parenthesis.

Table 5 reveals that, as expected, the higher the income, the higher the probability of being willing to pay with respect to not being willing to pay (the base case), that is to saying '*yes*' with respect to saying '*no*'. This holds for any level of stated income: EUR 1,000-3,000; EUR 3,000-5,000; more than EUR 5,000 with respect to the missing category "< EUR 1,000". The effect of income is mitigated for students who answered '*do not know*' with respect to those who answered '*no*'; however, in some cases, income still retains its statistical significance.

Coefficients on age variables are statistically significant at either 1% level or 10% level. The probability of falling into the '*yes*' category is higher for students aged 26-30 with respect to older students. In contrast, the model suggests no significant differences between students answering '*do not know*' compared to those declaring '*no*' with some exceptions regarding students above 35 years of age. Moreover, although most coefficients are not statistically significant, the negative signs on students aged 31-35 and older than 35 suggest that the probability of paying is likely to be higher in younger students than in older ones, *ceteris paribus*. Yet, the negative sign remains even when we use the availability of a personal income (unreported regression) rather than the family income, confirming an inverse relationship between age and WTP '*yes*', once income has been netted out. Although this evidence is in line with the literature, some caution is needed in interpreting coefficients regarding older respondents, as they only represent about 5% of the sample (see Table 1).

We were particularly interested in detecting whether the willingness-to-pay preferences are correlated to preferences for science or technology, as expressed by the choice of a university curriculum. University degrees in social sciences and the humanities, however, did not display statistically significant coefficients. The lack of significance suggests two things. On the one hand, the type of curricula did not discriminate between the available '*yes'*, '*do not know'* and *'no'* options. This is not a surprising result, since on-line news and TV programs are the sources of information about the LHC that were most quoted by the interviewees, while only 20% of the sample indicated university activity. On the other hand and in our context, this indicates that students enrolled in social sciences and humanities faculties are willing to pay for basic science at least as much as students enrolled in scientific curricula. This result is entirely new in the literature, as it is based on a question attached to a specific sum of money.

With respect to family composition and gender, our model suggests that no significant family composition differences exist in relation to the willingness to pay for basic research; in contrast, the female variable discriminates between male and female only in Specification 1, Column '*Yes*' supporting the idea according to which science is still a male-dominated field. Actually, gender loses its predicted power in explaining the willingness to pay that once controlled personal interest and attitude towards science-related matters.

The variables representing knowledge of research at the LHC, personal values, attitude and interest toward science are, as expected, strong drivers of being willing to pay.

The "A2 Particle accelerator" variable is positively associated with willingness to pay, i.e. respondents who are able to identify a RI with a particle accelerator are more likely to answer '*yes*' than '*no*', compared to respondents who did not recognise the LHC as a RI , *ceteris paribus*.

[10] In model 2, we omit the variable "B3 Having heard about the Higgs boson" because it is highly correlated with "B1 Having heard about the LHC" (Table 5: coeff = 0.46; p-value <0.05)

In line with the literature, judging funding research infrastructures important and having heard about the LHC jointly have a positive and statistically significant impact on answering '*yes*' rather than '*no*'; in contrast, knowing what a RI is and having some interest in research activities show no significant correlation at all with a '*yes*' response and in some cases even have a negative correlation.

However, the coefficient of "B5 Having visited CERN" displays a negative and significant coefficient in contrast with the available literature. As noted above, these anomalies are likely due to the presence of correlation between variables. This leads us to Specification 3, where variables expressing personal values and attitudes are replaced by factor scores. As expected, both the awareness of LHC-related activities and the attitude towards science are powerful predictors of a positive willingness to contribute, being statistically significant at 1% level.[11]

Finally, the likelihood ratio test in the three models indicates that variation in independent variables explains a good proportion of variability in the response variable. Test statistics and p-values, resulting from the Hausman test for the IIA assumption, associated to each model are reported in the last two rows of Table 5. Not statistically significant p-values indicate that the IIA hypothesis holds, providing further credibility to the use of a MNL procedure with respect to alternative models. Zero values of IIA test statistics replace negative values, which in turn, is evidence that the IIA holds as well (Cheng and Long, 2007).

[11] Note that in Specification 3 there is a general absence of statistical significance of variables entering the '*I do not know*' equation, suggesting that , for this particular specification, '*No*' and '*I do not know*' answers are pretty similar in nature, apart from the intercept term. We interpret this result to mean that the odds of supporting the research activity at CERN is still statistically different among people who answered '*I do not know*' compared to people who said '*no*'; however, we suspect that the factors' scores are not able to significantly discriminate between '*I do not know*' and '*no*' answers.

Table 5. Determinants of WTP. Multinomial logit estimates of participation equations (1 and 2) Base outcome *'no'*

	SPECIFICATION 1		SPECIFICATION 2		SPECIFICATION 3	
	Yes	I do not know	Yes	I do not know	Yes	I do not know
Family income						
1,000 - 3,000	0.33	0.38	0.35	-0.12	0.35*	-0.12
	(0.22)	(0.28)	(0.22)	(0.30)	(0.2)	(0.30)
3,000 – 5,000	0.53**	0.49*	0.55*	0.50*	0.55**	0.45
	(0.25)	(0.30)	(0.25)	(0.30)	(0.25)	(0.31)
> 5,000	0.71**	0.38	0.85***	0.30	0.73***	0.14
	(0.29)	(0.38)	(0.30)	(0.40)	(0.30)	(0.38)
Female	-0.41**	-0.01	-0.19	0.02	-0.25	0.03
	(0.19)	(0.15)	(0.20)	(0.16)	(0.20)	(0.16)
Age						
26-30	1.25***	0.44	1.18***	0.42	1.26***	0.40
	(0.32)	(0.26)	(0.35)	(0.30)	(0.34)	(0.29)
31-35	-0.73	0.06	-0.69	0.11	-0.81	0.05
	(0.66)	(0.39)	(0.65)	(0.40)	(0.66)	(0.39)
> 35	-0.10	-0.94*	-0.35	-1.03*	-0.26	-0.94
	(0.64)	(0.58)	(0.63)	(0.60)	(0.60)	(0.61)
SSH	-0.08	-0.04	0.07	-0.03	0.12	-0.03
	(0.20)	(0.15)	(0.21)	(0.16)	(0.21)	(0.16)
Household composition						
3-5	-0.03	-0.14	0.001	-0.16	0.02	-0.15
	(0.31)	(0.23)	(0.33)	(0.23)	(0.33)	(0.23)
> 5	-0.43	-0.32	-0.25	-0.33	-0.32	-0.33
	(0.48)	(0.31)	(0.49)	(0.32)	(0.50)	(0.51)
A1 Knowing what a RI is			-0.39	-0.21		
			(0.23)	(0.17)		
A2 Particle accelerator			0.60***	0.22		
			(0.21)	(0.17)		
A4 Interest in research			0.039	-0.09		
			(0.28)	(0.18)		
A6 Importance of funding RI			0.65***	0.19*		
			(0.18)	(0.10)		
B1 Having heard about LHC			0.57**	-0.001		
			(0.23)	(0.17)		
B5 Having visited CERN			-0.61*	-0.64**		
			(0.33)	(0.25)		
Awareness about LHC research					0.25***	-0.01
					(0.08)	(0.65)
Attitude towards science					0.27**	0.03
					(0.11)	(0.77)
Constant	0.39	0.97***	-2.73***	0.39	0.10	0.97**
	(0.45)	(0.34)	(0.95)	(0.58)	(0.46)	(0.34)
Country-fixed effects	yes	yes	yes	Yes	yes	yes
Observations	1,008	1,008	1,008	1,008	1,008	1,008
McFadden's R2	0.08		0.12		0.10	
Log Likelihood	-951.2		-912.3		-936.3	
Likelihood ratio test	177.9		255.2		207.2	
Hausman test for IIA						
Test statistic	0.00	1.44	0.00	0.00	0.00	6.26
p-value	-	0.92	-	-	-	0.98

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively.

Results from level equations (3) and (4) are shown in Table 6. It investigates the determinants of being willing to pay conditional on a lump-sum payment of 30 EUR. There are no significant changes with respect to the findings in Table 5, suggesting that, conditional to our sample, the analysis is quite robust. It should be noted, however, that the income variable is now, as expected, much more significant in explaining a '*yes*' response than in the previous case.

Table 6. Determinants of WTP. Multinomial logit estimates of the level equations (3 and 4)
Base outcome *'no'*

	SPECIFICATION 1		SPECIFICATION 2		SPECIFICATION 3	
	Yes	I do not know	Yes	I do not know	Yes	I do not know
Family income						
1,000 - 3,000	0.57***	0.34	0.57***	0.25	0.54**	0.22
	(0.22)	(0.30)	(0.22)	(0.31)	(0.22)	(0.32)
3,000 – 5,000	0.63***	0.55*	0.65**	0.55*	0.63***	0.51
	(0.23)	(0.33)	(0.23)	(0.34)	(0.23)	(0.35)
> 5,000	1.01***	1.20***	1.05***	1.07***	0.97***	0.95**
	(0.30)	(0.39)	(0.30)	(0.40)	(0.30)	(0.40)
Female	-0.12	0.06	0.14	0.07	0.09	0.06
	(0.21)	(0.15)	(0.22)	(0.16)	(0.21)	(0.16)
Age						
26-30	0.91***	0.30	0.80**	0.30	0.91***	0.33
	(0.33)	(0.26)	(0.34)	(0.26)	(0.33)	(0.26)
31-35	-0.06	0.01	-0.26	-0.09	-0.26	-0.05
	(0.66)	(0.39)	(0.65)	(0.40)	(0.66)	(0.40)
> 35	0.17	-1.22*	-0.03	-1.25*	-0.04	-1.29
	(0.60)	(0.68)	(0.60)	(0.68)	(0.61)	(0.70)
SSH	-0.15	-0.08	0.08	-0.03	0.12	-0.24
	(0.21)	(0.15)	(0.22)	(0.16)	(0.22)	(0.16)
Household composition						
3-5	-0.64*	-0.32	-0.60*	-0.34	-0.54	-0.32
	(0.33)	(0.24)	(0.34)	(0.23)	(0.34)	(0.25)
> 5	-0.51	-0.25	-0.38	-0.23	-0.28	-0.21
	(0.47)	(0.33)	(0.49)	(0.33)	(0.49)	(0.33)
A1 Knowing what a RI is			-0.29	-0.05		
			(0.23)	(0.17)		
A2 Particle accelerator			0.70***	0.38**		
			(0.23)	(0.16)		
A4 Interest in research			0.58*	-0.46**		
			(0.32)	(0.21)		
A6 Importance of funding RI			0.49***	0.05		
			(0.18)	(0.10)		
B1 Having heard about LHC			0.27	-0.19		
			(0.23)	(0.17)		
B5 Having visited CERN			0.22	0.10		
			(0.32)	(0.25)		
Awareness about LHC research					0.28***	-0.02
					(0.08)	(0.06)
Attitude towards science					0.40**	0.14**
					(0.13)	(0.07)
Constant	-0.02	0.15	-3.20***	-0.45	-0.43	0.15
	(0.50)	(0.34)	(1.03)	(0.55)	(0.54)	(0.35)
Country-fixed effects	yes	yes	yes	Yes	yes	yes

Observations	1,009	1,009	1,009	1,009	1,009	1,009
McFadden's R2	0.09		0.11		0.10	
Log Likelihood	-915.1		-891.3		-900.0	
Likelihood ratio test	176.9		223.6		206.3	
Hausman test for IIA						
Test statistic	0.00	14.4	0.52	0.00	0.14	4.18
p-value	-	0.42	1.00		1.00	0.99

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively.

When the preferences for the LHC research were investigated by asking for a single lump-sum payment, only 15% of respondents were certain to be willing to pay EUR 30. This distribution lies on the respondents' reaction to the presented bid. So, one might ask to what extent a positive willingness to pay exists below that threshold. In order to deal with this issue, we repeated our experiment by asking for a lower annual payment of EUR 0, EUR 0.5, EUR 1 and EUR 2. The '*yes*' responses, indicating a positive willingness to pay, increased from 14% to 73%. Table 7 investigates the drivers of such a decision-making process by estimating an ordered logistic model where the WTP variable is an ordered discrete variable as shown by equation (5).

Table 7. Determinants of WTP. Ordered logit estimates.

	SPECIFICATION 1	SPECIFICATION 2	SPECIFICATION 3
Family income			
1,000 - 3,000	0.37**	0.35**	0.32*
	(0.18)	(0.18)	(0.18)
3,000 – 5,000	0.45***	0.40**	0.40**
	(0.19)	(0.20)	(0.19)
> 5,000	0.62***	0.56**	0.55**
	(0.25)	(0.24)	(0.24)
Female	-0.10	0.02	0.04
	(0.12)	(0.13)	(0.13)
Age			
26-30	0.12	-0.15	-0.14
	(0.21)	(0.21)	(0.21)
31-35	-0.54*	-0.62*	-0.65*
	(0.32)	(0.36)	(0.36)
> 35	-0.72*	-0.92*	-0.88*
	(0.43)	(0.49)	(0.48)
SSH	-0.16	-0.02	0.09
	(0.13)	(0.13)	(0.13)
Household composition			
3-5	0.23	0.22	0.22
	(0.18)	(0.18)	(0.18)
> 5	-0.11	-0.04	-0.02
	(0.27)	(0.28)	(0.28)
A1 Knowing what a RI is		0.12	
		(0.13)	
A2 Particle accelerator		0.28**	
		(0.13)	
A4 Interest in research		0.16	
		(0.16)	
A6 Importance of funding RI		0.38***	
		(0.09)	
B1 Having heard about LHC		0.43***	
		(0.13)	
B5 Having visited CERN		0.10	
		(0.22)	
Awareness about LHC research			0.24***
			(0.05)
Attitude towards science			0.20***
			(0.06)
τ_1	-1.44***	0.79*	-1.28***
	(0.27)	(0.46)	(0.27)
τ_2	-1.03***	1.21***	-0.86***
	(0.27)	(0.46)	(0.27)
τ_3	-0.07	2.22***	0.14
	(0.26)	(0.47)	(0.27)
Country-fixed effects	yes	yes	yes
Observations	993	993	992
McFadden's R2	0.03	0.05	0.05

Log Likelihood	-1,200	-1,173	1,179
Likelihood ratio test	77.1	128.7	119.3

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively.

Income enters positively and significantly in each of the three proposed models confirming that the higher the income, higher the probability of choosing higher bids. For instance, belonging to a family with a monthly income of between EUR 1,000 and EUR 3,000 increases the probability of declaring to be willing to pay EUR 2 compared to a student belonging to a family with an income of less than EUR 1,000, *ceteris paribus*.

Again, older students, above 31 years of age, are likely to pay less than their younger peers under 26; in contrast, demographic characteristics, such as household composition and the type of education are not significant determinants of payment outcomes. The latter result suggests that students in the humanities and social sciences do not behave differently from students in scientific faculties in choosing among the levels of the proposed bids.

As expected, being aware about LHC research and having a positive attitude towards science significantly drive the distribution of willingness-to-pay responses across the bids. This finding holds both when original variables (Specification 2) and factor scores (Specification 3) are used.

Taos (τ) parameters refer to the thresholds used to differentiate the adjacent levels of the dependent variable. They are statistically significant, justifying the use of three categories of the level of willingness to pay upon combining some categories.

As a final exercise, we provided a preliminary computation of the mean individual WTP for research activity at CERN. For instance, by assuming that those who decline to pay EUR 30 have zero WTP, while those voting yes are willing to pay exactly EUR 30, the mean WTP would amount to EUR 4.5 per person *una tantum*.[12] It should be noted that these figures are very conservative since people who voted '*yes*' to EUR 30 may be willing to pay more than this amount; while WTP for people who voted '*no*' may fall in the range between EUR 0 and EUR 30 instead of being EUR 0, as confirmed by answers related to the annual payment system with bids amounting to EUR 0.5, EUR 1, and EUR 2. Further analysis and more appropriate techniques have to be implemented to fine-tune individual WTP and calculate an aggregate WTP for basic research at CERN's LHC. In truth, a contingent valuation experiment, whose results will be available for further research with a representative sample of taxpayers in one CERN member state has recently been carried out.

6 Concluding remarks

Big Science has been considered the contemporary cultural equivalent of building pyramids or cathedrals because of its highly symbolic value. In the words of Weinberg (1961, p.161): "History… will find in the monuments of Big Science – the huge rockets, the high-energy accelerators, the high-flux research reactors – symbols of our time just as surely as she finds in Notre Dame a symbol of the Middle Ages".

Like cathedrals, large-scale RIs are costly, and governments often ask to what extent they should fund them, particularly in the domain of basic science. This study represents an initial analysis of factors driving the demand for basic science, and specifically, the discovery potential at the LHC, as an example of a highly visible RI that generates knowledge that has still not been associated to any predictable application. We empirically show that there is a willingness to pay for basic research, which amounts, conditional to our sample, to EUR 4.5 per person *una tantum*. This amount is relatively small compared to WTP studies in cultural economics, e.g. Hansen (1997), Santagata and Signorello (2000), Pollicino and Maddison (2001) and Alberini e Longo (2006), but we do not claim that our survey is representative of the

[12] We are thankful to an anonymous referee for suggesting this approach. The '*I do not know*' answers were excluded from the computation. Moreover, in this pilot experiment, we limited the computation of the mean WTP by only exploiting the question asking for the lump-sum payment of EUR 30. See Florio et al. (2016) for the mean WTP when yearly payments of EUR 0, EUR 0.5, EUR 1 and EUR 2 are considered.

general population's attitudes. We were actually interested in performing an exploratory analysis of how social attitudes towards science can lead to a positive willingness to pay, and our findings point to such evidence. Specifically, our findings should prove particularly useful for both research and policy. From a research perspective, we empirically show, by surveying students in four countries, that there is a positive social attitude, proxied by the willingness to pay for basic research, at least among the educated young. The willingness to pay for science is, as expected, fueled by the respondent's financial situation, i.e. the greater the income, the more likely it will be to obtain a *'yes'* response, and by personal values and attitudes , i.e. by being personally interested in scientific research in general; by having a positive attitude toward science, and finally, by having heard what CERN and the LHC are. Perhaps surprisingly, and this is our most interesting finding, such results independently consider whether the respondents are enrolled in science or non-science related curricula. The latter emphasises the role of the outreach of science and propagation effects through the media.

On the policy side, public preferences are one of the factors to be considered in determining the budget allocation for funding RIs to ensure successful strategies and changes. This study provides an analysis of demand-side factors of the willingness to pay for Big Science as a pure public good. This seems particularly important in this field since the construction of large-scale RIs has been often driven, mainly, by supply-side factors such as the availability of the required technology and research questions from within scientific communities.

We conclude with a caveat and indications for future research. Our focus in this pilot exercise was on the young undergraduates cohort in line with other related WTP experiments (e.g. Fudenberg et al. 2012, Wang et al. 2005), but further research on the population of tax payers is needed. A sample of taxpayers would provide useful insights about differences in willingness to pay behaviour and attitudes towards basic science issues. Therefore, the next step should target a representative sample of taxpayers in countries supporting large scale RIs (for instance CERN Member States). Moreover, instead of *a priori* fixed bids for the whole sample, it would be interesting to design a contingent valuation-like experiment with a range of bids for different sub-samples or asking an open-ended question related to the maximum WTP (see Florio and Giffoni 2017). Alternatively, one may think that there is some purpose for testing WTP for basic research by stated choice experiments along the path of the environmental economics literature in this area (DeShazo and Fermo, 2002; Scarpa, 2008). with all the due caution because of the novelty of the fieldFor instance, one may consider different possible features in the design of a proposed big science project before its actual implementation.

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ANNEX I - QUESTIONNAIRE

The willingness-to-pay for the Research Infrastructures

University:	*Faculty:*

SECTION A	
A.1. Do you know what a research infrastructure is?	□ YES □ NO
A.2. In your opinion, which of the following is a research infrastructure? *For this question it is possible to choose multiple answers.	□ TELESCOPE □ INSTRUMENT OF DATA COLLECTION AND ARCHIVE □ DATA ELABORATION SOFTWARE □ PARTICLE ACCELERATOR □ LIBRARY □ COMPUTER □ ASTRONOMICAL OBSERVATORY □ PLANETARIUM
A.3. Can you give an example of a research infrastructure that you know/that you visited or that you heard of?	
A.4. Are you interested in scientific discoveries and in research activities in general?	□ YES □ NO
A.5. If yes, please indicate your source of information.	□ TV □ Radio □ Specialised magazines □ Online news □ Other (please specify)
A.6. On a scale from 1 (useless) to 5 (fundamental), how do you rate the importance of funding research infrastructures?	□ Useless □ Insignificant □ Important enough □ Important □ Fundamental
A.7. Can you briefly explain the motivations for your answer on the previous question?	

<u>LARGE HADRON COLLIDER (LHC)</u>

<u>What is the LHC?</u>

The Large Hadron Collider (LHC) is the biggest and most powerful particle accelerator ever built. It can accelerate hadrons (protons and heavy ions) up to 99,9999991% of speed of light and make them collide currently reaching an amount of energy, in the mass centre, of 8 teraelectronvolts (TeV) (it is expected that, in 2015, this energy will reach near 14 TeV, which is the full capacity of the infrastructure).

It's located at CERN close to Geneva and is built inside an underground 27 km-long tunnel that spans the border between France and Switzerland and sits between Geneva airport and the Jura mountains, originally excavated to build the Large Electron-Positron Collider (LEP).

The tunnel is located at an average depth of 100 metres.

It is formed of about 2,000 superconductive magnets, maintained at a temperature of -271 °C. The low temperature serves to create the phenomenon called superconductivity in the magnets: this way much less energy is consumed and it is possible to accelerate particles at high energies. The machine accelerates two particle beams circulating in opposite directions, each of them contained in a vacuum tube. Those then collide in four points along the orbit, in correspondence with caverns where the tunnel widens in large experimental halls. In these stations there are four principal particle physics experiments : ATLAS (A Toroidal LHC Apparatus), CMS (Compact Muon Solenoid), LHCb (LHC-beauty) and ALICE (A Large Ion Collider Experiment). Those enormous experiments consist in a large number of detectors that use different technologies and operate around the point where the beams collide. During collisions, thanks to the transformation of energy into mass, a large amount of particles is produced whose properties are measured by the detectors. The two smallest detectors are TOTEM and LHCf.

The entry into operation of LHC, originally scheduled for the end of 2007, took place on September 10, 2008.

What is the purpose of the LHC and its experiments?

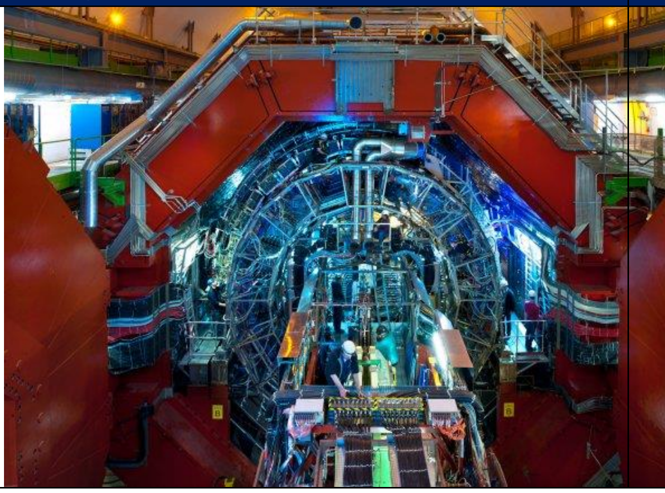
LHC is used for experimental research in the field of particle physics. In particular, it serves to discover what the vast majority of matter and energy contained in the universe is made of. Today we know of the existence of dark matter and dark energy, but we do not know what they are made of. In July 2012, the LHC reached its first big achievement: it "saw" the famous Higgs bosons, the particle whose field allows all particles to have a mass. Each experiment has a specific research activity:

- **ATLAS and CMS:** are general-purpose experiments that revealed the Higgs boson and are dealing with research that includes supersymmetry**.**
- **ALICE**: investigates quark-gluon plasma, a state of matter that existed in the first moments after the Big Bang.
- **LHCb**: studies the asymmetry between matter and antimatter.
- **LHCf**: uses particles thrown forward by LHC collisions to simulate cosmic rays.
- **TOTEM**: precisely measures protons as they emerge from collisions at small angles.

ATLAS	CMS

ALICE

LHCb



In the future, the LHC may also discover the existence of supersymmetrical particles and push us to think that the universe is not made of only four dimensions as we perceive (right-left, up-down, back-forth, plus the time dimension) but by many other dimensions invisible to us, rolled up on themselves. The LHC may help us understand:

- ✓ Why the matter we are made of is so stable;
- ✓ Why the universe is expanding faster than expected;
- ✓ Why the universe seems to be made of 95% of something that we do not see and we do not know, but acts on galaxies and therefore appears to exist.

SOURCE: Text extracted from *Wikipedia (28/05/2014)*
https://en.wikipedia.org/wiki/Large_Hadron_Collider

SEZIONE B	
B.1. Did you hear about the LHC before this questionnaire?	□ YES □ NO
B.2. If yes, please indicate your source of information.	□ School/university □ TV □ Magazines □ Internet □ Friends □ Other (please specify)
B.3. Did you ever hear of the"Higgs boson"?	□ YES □ NO
B.4. If yes, please indicate your source of information.	□ School/university □ TV □ Magazines □ Internet □ Friends □ Other (please specify)
B.5. Have you ever been to CERN?	□ YES □ NO
B.6. If yes, please indicate how many times?	□ once □ twice □ more than twice
B.7. In your opinion, what is the purpose of the LHC? *For this question it is possible to choose multiple answers.	□ it is an useless machine whose construction could have been avoided. □ it is a machine that affects only the world of physicists ' and scientists. . □ it is a dangerous machine for the risk of nuclear accidents. □ it is a useful machine for energy production. □ it is a useful machine with experiments with protons' acceleration which can be used for different purposes.
B.8. Would you be willing to provide an economic contribution to fund the research activity of the LHC?	□ YES □ NO □ I DON'T KNOW
B.9. Could you please explain why you would be **(or WOULDN'T be)** willing to fund the research activity of the LHC?	
B.10. By 2015, would you be willing to offer an economic contribution equal to 30 Euro (lump sum), turning down other personal expenses?	□ YES □ NO □ I DON'T KNOW
B.11. Could you please explain why would you be **(or WOULDN'T be)** willing to pay a sum equal to 30 euro lump sum?	
B.12 If someone asks you to give an economic contribution to the LHC by means of an annual tax over a period of 30 years, would you be willing to pay an annual amount equal to:	□ 2 EURO □ 1 EURO □ 0.50 EURO □ 0 EURO
B.13. Could you please explain why you would be willing to pay this contribution?	

SEZIONE C	
C.1. Age:	□ 19-25 □ 26-30 □ 31-35 □ more than 35 years old
C.2. Sex:	□ M □ F
C.3. City of residence:	
C.4. What is your educational background (pre-university):	□ scientifical □ classical technical □ Other (please specify):
C.5 What was your average score during your pre-university studies?	□ Pass (50-59) □ Merit (60-69) □ Distinction (>70)
C.6. In which of the following brackets does your family monthly net income fall?	□ up to 1,000 Euro □ from 1,000 to 3,000 Euro □ from 3,000 to 5,000 Euro □ more than 5,000
C.7. Do you have your own personal income?	□ YES □ NO
C.8. Household composition (including parents, brothers/sisters):	□ 1-2 □ from 3 to 5 □ more than 5