WILLINGNESS-TO-PAY FOR SCIENCE AS A PUBLIC GOOD: A CONTINGENT VALUATION EXPERIMENT

MASSIMO FLORIO FRANCESCO GIFFONI

Working Paper 17/2017

NOVEMBER 2017

UNIVERSITÀ DEGLI STUDI DI MILANO

DIPARTIMENTO DI ECONOMIA, MANAGEMENT E METODI QUANTITATIVI

Via Conservatorio 7
20122 Milano
tel. ++39 02 503 21501 (21522) - fax ++39 02 503 21450 (21505)
http://www.economia.unimi.it
E Mail: dipeco@unimi.it

WILLINGNESS-TO-PAY FOR SCIENCE AS A PUBLIC GOOD: A CONTINGENT VALUATION EXPERIMENT

Massimo Florio[1] and Francesco Giffoni[2]

[1] Dept. of Economics, Management and Quantitative Methods, University of Milan, Via Conservatorio 7- 20122, Milan, Italy. Email: massimo.florio@unimi.it

[2] Centre for Economic and Social Research Manlio Rossi-Doria, Rome Tre University, Via Silvio D'amico, 77 – 00145, Rome, Italy. Email: francesco.giffoni@uniroma3.it

Abstract

Every year a significant amount of money is invested by governments on large-scale research infrastructures such as particle accelerators, telescopes, robotic space probes, biological data banks, oceanographic vessels, etc. The majority of these projects is funded through general taxation, and hence taxpayers are implicitly called to contribute to scientific discovery. Against the actual tax burden, how much the general public is actually willing to pay for investment in science? This paper explores the attitudes of young science-outsiders (the taxpayers of tomorrow) by the design of a pilot experiment involving a sample of undergraduate students in economics at University of Milan. We were interested in building a replicable survey setting aimed at eliciting the willingness to pay (WTP) for the discovery potential of a basic science project. Our case study is the Large Hadron Collider (LHC), the most powerful particle accelerator worldwide. The experiment takes the form of a Contingent Valuation Referendum-like in depth interview. Both parametric and non-parametric estimators were used to calculate the mean WTP. Our results suggest that the sample mean WTP for the LHC discoveries ranges from EUR 23 to 28 per person annually. This is a relatively high result, several times in excess of the actual average tax-burden for supporting the CERN budget by Italian taxpayers, but can be compared with several previous empirical findings about the WTP for the non-use value of specific cultural and environmental goods. Building on this pilot experiment, we discuss possible future research avenues in order to extend to representative samples of taxpayers the empirical analysis of WTP for scientific discovery.

Keywords: Research Infrastructures, Willingness-to-Pay, Science as Public Good, Non-Use Value, Large Hadron Collider

JEL Codes: C83, D61, I23, O32

1. Introduction

Discovery is not a free lunch. According to some estimates (Science|Business, 2015), the world spends more than $1 trillion a year on basic research and R&D. The total capital and operations costs of some very large-scale research infrastructures (RIs, hereafter) such as the International Space Station, the Square Kilometers Array Radiotelescope, the Human Genome Project, are in the region of billions euro. The present value to 2025 of the Large Hadron Collider (LHC) total costs has been estimated around EUR 13.5 billion[1] (Florio et al., 2016), while the High-Luminosity Large Hadron Collider (HL-LHC) project aiming at cranking up the performance of the LHC after 2025 in order to increase the potential for discoveries is budgeted by CERN CHF 950 million (about EUR 810 million) for construction expenditure only (Rossi, 2017). ITER, the experimental international fusion reactor, is taking more than € 16 billion to be built (Reuters, 2016). The capital expenditure for the construction (phase 1) of the Square Kilometre Array, the world's biggest radio telescope, now under development in South Africa and Australia, is estimated to be EUR 650 million; while the operating costs of the project (phase 2) are not yet established.[2] The cost of the Human Genome Project has been estimated around USD 3 billion (about EUR 2.5 billion).[3] Even relatively minor RIs, only supported by national governments, such as the CNAO research centre for hadron therapy in Pavia (Italy) or the ALBA synchrotron supported by the Spanish government[4] have costs in the region of hundreds million euro (Battistoni et al., 2016; Biscari et al. 2012; Sanz-Menéndez et al., 2013).

All these scientific projects are funded either by international and national agencies through government funding, hence ultimately by taxpayers. Stakeholders agree that science, and specifically fundamental research producing basic knowledge whose benefits are likely to widespread and diffuse worldwide, must be supported by governments (Stiglitz, 1999). Is it worth for the taxpayers to fund such projects? Does the society perceive Big Science as a valuable investment? These questions are interesting for both academic research and science policy. From the academic research perspective, the questions is particularly intriguing when basic research is considered, since its definition acknowledges that it has 'no use'.[5] Florio and Sirtori (2016) argue that, as in the case of the existing value of environmental and heritage public goods, the general public may have a preference (i.e. an increasing utility) for the production of new knowledge *per se* even if there is no predictable use of it. Can we gauge this preference?

Since 2008, budget austerity has been forcing governments around the world to weigh carefully the economic and social benefits of all their investments, so from the science policy perspective there is great concern related to the allocation of resources for the conduct of science towards the goal of best serving the public interest and how the general public perceives this effort (European Commission, 2016). Indeed, the main benefits generated by RIs such as the creation of knowledge outputs, technological externalities, human capital accumulation, cultural impact of the outreach, and service provision may only capture the use value of these assets. In order to estimate their total economic value, the benefits related to the non-use value should be also considered (Johansson, 2016). As stated by Johansson and Kriström (2015, p. 24): "If the project being evaluated affects non-use values, this should be reflected in the cost-benefit

[1] Estimated in 2013 prices; total costs include construction and operation costs net of scientific personnel salaries.
[2] http://skatelescope.org/project/
[3] https://www.genome.gov
[4] http://www.gencat.cat/web/multimedia/eng/sincrotro/index_htm.htm
[5] OECD (2002) defines basic research 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'.

analysis". For these reasons, it is a timely need to examine the WTP for scientific discovery, even when, as in the case of the Higgs boson or the gravitational waves, there are no particular applications or use in view.

This paper investigates the WTP for particle physics research at LHC by a pilot experimental setting, drawing from the empirical literature on the valuation of non-use benefits of environmental or cultural goods. A sample of 230 undergraduates at University of Milan have been involved in a Contingent Valuation referendum-like (DCCV)[6] survey , where some questions were designed to elicit the respondents' WTP and other to control for individual variability of some characteristics. Given the relatively small sample size and low heterogeneity of participants, our study should be intended as a "laboratory" experiment; namely, it is an attempt to learn how to estimate the WTP for basic research by examining the preferences of young respondents not involved in science. We use both parametric and non-parametric estimators to calculate the mean WTP of the respondents. Our econometric results suggest that WTP for the LHC discoveries is about EUR 25 per person annually for the sample. This is a relatively high price tag, in excess of the actual average tax-burden for supporting the CERN budget, but of comparable size with several previous empirical findings about the WTP for the non-use value of specific cultural and environmental goods (among others Grazhdani et al., 2013; Amirnejad et al., 2006; Carson et al., 2003; Thomson et al., 2002; Hansen, 1997).

The paper is structured as follows. Section 2 briefly describes the analytical framework. Section 3 presents our experiment design. Results are reported in Section 4. Section 5 concludes by discussing some lessons from the experiment and the further research needed to extend it to representative sample of taxpayers.

2. Analytical framework

Conceptually, the WTP for discovery can be interpreted as the individual preference for acquiring new knowledge, which, as suggested by Stiglitz (1999) is a global public good. An essential feature of discovery, that is knowledge, is its non rivalrousness – the consumption of one individual does not exclude the consumption of another - and its non-excludability, which implies that no one can be excluded for consumption once it has been produced. While the potential economic value of discovery, if any, can be protected by patents or other legal constraints to incentives the private provision of knowledge, basic research and other fundamental forms of knowledge for development should be not protected by any intellectual property regime and public support is required (Stiglitz, 1999; Romer 1986; Arrow, 1962). Knowledge is not only a public good, but in the words of Stiglitz (1999), it is a '*global or international public good*' as once produced, its consumption is typically not bounded in one specific locality, but its benefits widespread worldwide. Therefore, when taxpayers fund science in one country, they actually generate an externality to other taxpayers elsewhere.

As for many years there will be no market for (most) knowledge generated by a discovery in basic science, there are no prices to convey signals to investors, therefore governments must rely on taxes. The theory of taxation for public goods suggests that citizens' preferences, elicited by some detection mechanisms, should be considered as pseudo-prices (Hindriks and Myles, 2013) and that the optimal provision of a pure public good requires that the sum of the individual WTP

[6] The referendum-like approach is also known as single-bounded dichotomous choice approach.

equals the production cost. While such costs are observable variables, or can be predicted when designing a RI, the individual WTP is a private information, and different elicitation methods have been suggested and implemented in the applied welfare economic literature (Johansson and Kriström, 2015; Florio, 2014).

In order to estimate the WTP for scientific discoveries, we discuss both the use of parametric estimators based on the logistic distribution and distribution-free non-parametric estimators. Over the last decades researchers have started to argue that parametric estimation relies on quite strict *a priori* assumptions about the underlying (logistic) distribution of WTP in the target population that are effectively not testable at operational samples sizes. In response to this argument, nonparametric and semiparametric methods started to receive more attention (Kristrom, 1990; Li, 1996; Cooper, 2002; Crooker and Herriges, 2004; Huang et al., 2008; Watanabe and Asano, 2009). The non-parametric approach can be applied either using Ayer et al's (1955) pooling adjacent violators algorithm or Turnbull's (1976) distribution-free estimator; the latter originally applied in contingent valuation by Carson et al. (2003) and Haab and McConnell (1997). For CV with discrete responses the Turnbull is similar to applications by Kristrom (1990) and McFadden (1994) of the pool adjacent violator algorithm.

These nonparametric estimators provide welfare measure estimates unconditional on psycho, socio-economic and demographics characteristics of the respondents, or characteristics of the good to be valued, preventing the researcher from carrying out scope tests as recommended by NOAA guidelines Arrow et al. (1993) and more recently by Johnston et al. (2017). However, they providing a benchmark which is robust to potential parametric specifications errors.

As a consequence, both parametric and non-parametric estimators are worth considering in applied welfare analysis of this kind since little is known about individual preferences on basic research.

2.1 Parametric estimation

The reference model to estimate the existence or intrinsic value of environmental and cultural goods is the utility difference model developed by Hanneman (1984). Let's assume that the dependent variable of interest, S_i $(i = 0,1)$ is a binary variable. S_i = 0 identifies individuals who would not be willing to pay for the public good being evaluated; in contrast, S_i = 1 identifies people willing to pay the bid proposed by the interviewer. Each individual has an indirect utility function of the form $V(M;\ Y_i;\ Z_i)$ where Y_i is income, Z_i is vector of exogenous variables affecting individuals' preferences, and M is a binary variable describing the state of the world with or without the good under evaluation, which, in our case, is (potential) scientific discovery and any new knowledge created by it over time.

When interviewed, the respondent has two options: (a) to answer '*no*' and face the state of the world in absence of the good ($M = 0$) and keep all of his/her income (Y_i); (b) to choose '*yes*' and thus having his/her income reduced by the bid (A) but the good available for the future ($M = 1$). An individual will respond '*yes*' if and only if his/her utility under option (b) is greater than or equal to that under option (a): $\delta V_i^* = V(1; Y_i - A;\ Z_i) - V(0; Y_i;\ Z_i) + v_i \geq 0$ where v_i is the error term with zero expected value.

Empirically, the probability that the individual accepts the offer (A) is approximated with a binomial logit model given by:

scope

$$\Pr(S_i = 1) = \Lambda(\delta V_i^*) = \Lambda\,(\alpha + A\beta_1 + Y_i\beta_2 + Z_i\beta_3\,) \quad (1)$$

where the latent variable δV_i^* measures the difference in utility, $\Lambda(.)$ is the logistic cdf of the error term v and $\alpha, \beta_1, \beta_2, \beta_3$ are the parameters of the model to be estimated, where $\beta_1 \leq 0$ and $\beta_2 > 0$ are expected. Once equation (1) is estimated, the expected value of WTP is obtained by numerical integration. According to Duffield and Patterson (1991) there are three methods to compute the value of WTP. The first one is to compute the WTP by integrating equation (1) from $-\infty$ to $+\infty$ obtaining the so called overall mean WTP. Since the WTP is nonnegative in our context, as we assume that nobody would pay to avoid a discovery (i.e. not less than a zero pseudoprice is attached to potentially harmful knowledge, if any), this method is not appropriate. The remaining two alternative approaches are to compute the expected value of the WTP by integrating equation (1) from 0 to $+\infty$ or the truncated mean WTP integrating it from 0 to maximum bid (A). Duffield and Patterson (1991) suggest that the truncated mean WTP is the most appropriate method because satisfies theoretical constraints (the upper limit of the WTP is not infinity but something less than income), is statistical efficient in the sense that reduces the influence of the upper tail of the empirical distribution of WTP and satisfies the aggregation criteria. By using this method the value of the maximum bid (A) has to be assigned to all recorded WTP above (A). Thus:

$$
\begin{aligned}
E(WTP) &= \int_0^{MAX\,A} \Lambda\big(\delta V_i^*(A)\big)\,\delta A = \\
&= \int_0^{MAX\,A} \left[+\exp\left(-\big(\hat{\alpha} + A\hat{\beta}_1 + Y_i + X_i\hat{\beta}_3\big)\right)\right]^{-1} \delta A \qquad (2) \\
&= \int_0^{MAX\,A} \big[1 + \exp\big(\hat{\alpha}^* + A\hat{\beta}_1\big)\big]^{-1} \delta A
\end{aligned}
$$

where $\hat{\alpha}^*$ is the estimated adjusted intercept wich was added by the socio-economic characteristics and other independent variables entering into the model to the original constant $\hat{\alpha}$.

2.2 Non-parametric estimation

The Turnbull's (1976) estimator is based on the estimation of a survivor function in presence of interval-censored data.[7] Following Bateman et al. (2002), the survivor function is defined as:

$$\hat{S}(A_j) = \frac{n_j}{N_j} \quad 0 \leq j \leq J \qquad (3)$$

where A_j is the offered bid and n_j/N_j is the percentage of '*yes*' responses in the sub-sample of respondents that received the bid A_j. In cases wherein the survivor function is not a non-strictly decreasing function, it will not generate a valid survivor function. To correct such problem, the Ayer et al.'s (1955) pooling adjacent violators algorithm can be employed (Bateman et al., 2002;

[7] By interval-censored data, we mean that a random variable of interest is known only to lie in an interval, instead of being observed exactly as in the case of DCCV. In such cases, the only information we have for each individual is that their WTP falls in an interval, but the exact amount is unknown.

Amponin et al., 2007). The technique includes pooling data for two adjacent bid levels if the estimate of the survivor function for the higher bid level is greater than that for the lower bid; that is:

$$\hat{S}(A_j) = \frac{n_j + n_{j+1}}{N_j + N_{j+1}} \quad 0 \leq j \leq J-1 \tag{4}$$

Once the survivor function is estimated, the mean WTP is given by:

$$E(WTP) = \sum_{j=0}^{J} \hat{S}(A_j)[A_j - A_{j-1}] \tag{5}$$

where the mean WTP is the sum of the probabilities of the respondent voting behaviour times the difference between two bid levels.

3. Experiment implementation and design

Our experiment was conducted at University of Milan in two rounds and it involved 230 undergraduate students in economics. In June 2016, 120 students were surveyed; the remaining 110 were interviewed after one year in June 2017. Data were treated confidentially and anonymity was guaranteed to all the participants in the experiment, who agreed to volunteer for the purpose of research.[8]

The experiment proceeded as follows. Several days prior to the experiment session, students were informed about the opportunity to take part in an upcoming research project and they were made aware that the participation in the experiment was on a voluntary basis. On the day of the experiment, upon arrival in the classroom, two expert interviewers gave participants a randomly-drawn, anonymized CV-like questionnaire containing an ID number. Different pre-printed bid (see below) were randomly assigned by groups, each containing around 40 students . Afterwards, students were partitioned to ensure that they could not communicate during the session, nor observe others in the room. To ensure anonymity, interviewers announced that information would be linked only to participants' ID-numbers and not to individual names; yet data would be elaborated in aggregate format only. Only participants and the interviewers were present in the experimental session.

Once all participants were seated and ready to fill in the questionnaire, interviewers began the session by reading a short introductory script. Participants were informed that they would be asked to complete a number of tasks (which interviewers would gradually describe to them) and make a number of choices. Importantly, prior to beginning the experimental tasks, and mainly in the first part of the experiment, participants were given no information about the aims of the research project, nor about what the experiment sought to elicit. These procedures were implemented to correctly measure opinions and interests in scientific issues and respondent prior awareness of the RIs without the "experimental" bias (Carson et al., 2003).

The questionnaire was designed to be consistent, as far as possible, with the NOAA panel guidelines by Arrow et al. (1993), while some modifications were applied to take into account the peculiarities of the public good under evaluation.

The questionnaire (available in Annex I) consisted of three parts. The first part described information and perception of a respondent about issues related to RIs in general as well as the

[8] The experimental protocol was in compliance with the regulations ratified by the ethics committee of the University of Milan Dean decree 19 July 2011.

respondent's interest in scientific discoveries. As showed by Heberlein et al. (2005), attitudes, interests, knowledge of the (public) good under evaluation can lead to different evaluations (and thus WTPs) by respondents; therefore attitudinal and behavioural scope sensitivity tests can be performed to validate and support results (see also Filippini et al., 2016).

The second part contained questions aiming at eliciting the WTP for scientific discoveries. First of all, a description of the LHC was provided to interviewees in the form of a shortened version of the Wikipedia entry "Large Hadron Collider", including five photos showing the particle accelerator in its 27-kilometre tunnel and the particle detectors ATLAS, CMS, ALICE and LHCb placed at four locations around the accelerator. In this way, respondents were given a common information set about the functioning of the LHC, its research activity, and the answers that scientists expect from this research facility. Students were explained that collisions are examined to find answers to issues left unsolved by the Standard Model of particles and forces[9] such as the origin of particles' mass, a comprehensive explanation of the interactions between the fundamental forces of the universe and the phenomena responsible for dark matter (Giudice, 2010). The description was previously and repeatedly revised to refine the information it presented and to improve its clarity by means of focus groups and pilot tests carried out at University of Milan in 2015, before the experiment took place (Catalano et al., 2016).

Just before asking the WTP questions, the questionnaire disclosed that the projects carried out by CERN, including the realisation of the LHC, are funded by the CERN Member States[10] through taxation, according to a share calculated on the respective national GDP, meaning that general public supports indirectly such projects and public contributions enable the CERN to continue its research activity. No information was however given about the actual amount of the Italian government contribution to the CERN budget.

The NOAA guidelines suggest to use a referendum-like approach according to which, people should be asked to state only '*yes*' or '*no*' to the proposed bid; in contrast, Hanemann (1984) and Carson (1985) have stressed the importance of follow–up questions addressed to estimate the maximum WTP value. The bid level offered in the follow–up question should be greater than that offered in the initial payment offer if the answer to the initial payment question is '*yes*', otherwise the follow-up procedure is stopped. Although this approach is statistically more efficient than referendum approach, Alberini et al. (1997) found that the average WTP estimated after the follow–up approach can be lower than that implied by the responses to the initial payment question. A possible explanation is that some respondents may treat the suggested bid as a signal for the quality of the good and/or might erroneously believe that the program to be valued in the follow–up is different from the initial one. Furthermore, in favour of the referendum approach there is the argument that it mimics behaviour in regular markets, where people usually purchase, or decline to purchase, a good at the posted price. It also closely resembles people's experience with political markets and propositions on a ballot (Mitchell and Carson, 1989). On the other side, single referendum elicitation format is highly vulnerable to anchoring effects (Green et al., 1998).

Although the debate is still open, in this exploratory attempt to elicit the WTP for basic science, we adopted a referendum-like approach, which seems the most accepted one in the current literature. Respondents were asked to vote '*yes*' or '*no*' to fund for the research activity at

[9] To further details on the main goals of the LHC and on a non-physicists understandable version of Standard Model of particles and forces see the LHC guide available at http://cds.cern.ch/record/1165534/files/CERN-Brochure-2009-003-Eng.pdf

[10] Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland, and United Kingdom.

the LHC given the amount of income reduction (e.g. the offer price). The exact wording of the WTP question was: "*Would you willing to pay EUR _ every year to fund the research activity at LHC turning down other personal expenses*? With one of the following pre-printed bids: EUR 1, EUR 2, EUR 5, EUR 10, EUR 15, EUR 30. The minimum and the maximum price offered to respondents was based on previous surveys aimed at calibrating the experiment (Catalano et al., 2016). For those who voted '*yes*', to get additional information, an open ended was asked to explain why they chose to vote for the program. For those who vote '*no*', the follow-up question was asked to identify protest bid respondents. Moreover, in order to collect further evidence about respondents' WTP, an open-ended question of the maximum WTP was added as well. Finally, the interviews were conducted by experienced researchers in order to minimize interview bias and strategic behaviour.[11]

The third part of the questionnaire included questions on the individuals' demographic and socio-economic characteristics such as age, sex, income (both personal income and family one) and household size.

4. Descriptive Statistics and Results

Data were analysed using both descriptive and econometric procedures. Table 1 shows descriptive statistics related to demographic and socio-economic characteristics of the respondents. The sample of interviewed is aged, on average, 22; while, 57% of the sample, i.e. 131 respondents is male. The distribution of respondents based on their monthly family income is: 91 (42.3%) belong to a family with a monthly income between EUR 1,000 and 3,000; 81 (37.7%) between EUR 3,000 and 5,000; 35 (16.3%) more than EUR 5,000 and 8 (3.7%) respondents belong to a family earning less than EUR 1,000. Only 50 (21.7%) students earn an own income. Almost all respondents (84%) belong to a family consisting of 3-5 components.

The income distribution of the respondents' families is comparable with the available data on income distribution in Italy. The average family income in our data is about EUR 32,700 per annum (EUR 2,645 per month) with respect to a national mean of about EUR 29,500.[12] While we did not design the experiment seeking for statistical representativeness of the Italian population which was not our objective, the family background of the respondents doesn't suggest a sample biased towards relatively high income levels (but certainly the educational background is higher than for the Italian average).

[11] Interview bias arises when the interviewer accidentally leads respondent in a particular direction when answering the questionnaire, while strategic behaviour occurs when a systematic error is introduced into the sampling, when respondents select one answer over others in order to not to reveal their true opinion/position. A well-known case is that of perceived government-supported surveys leading people to skip highly-sensible information like income.

[12] Data retrieved on April 18, 2017 from the Italian National Institute for Statistics (ISTAT). The distribution of the average family income in Italy is as follows: North-West EUR 32, 888; North-East EUR 32,700; Centre EUR 30,400; South EUR 24,400 and Islands EUR 22, 600. These data refer to disposable income in 2014 net of taxes, but gross of house rents. See for details http://dati.istat.it/Index.aspx?DataSetCode=DCCV_REDNETFAMFONTERED

Table 1. Descriptives of socio-economic characteristics; sample = 230

Variable	Mean	Std. Dev	Min	Max
Continuous Variables				
C1 Age (years)	21.8	3.8	19	54

Categorical variables	Code	Number	Percent	Total (number)
C2 Sex	0 = Female	99	43.0	230
	1= Male	131	57.0	
C6 Family income (EUR)	1= <1,000	8	3.7	215[a]
	2= 1,000-3,000	91	42.3	
	3= 3,000-5,000	81	37.7	
	4= > 5,000	35	16.3	
C7 Personal income	0 = No	180	78.3	230
	1 = Yes	50	21.7	
C8 Household Composition	1 = 1-2	30	13.3	
	2 = 3-5	189	83.6	226[b]
	3 = > 5	7	3.1	

Question C1: Age; Question C2: Sex; Question C6: Family income; Question C7: Availability of a personal income; Question C8: Household Composition (all members); [a] 15 observations are missing; [b] 4 observations are missing.

Results of the investigation about awareness and perception of RIs and interest in science of respondents are shown in Table 2, Table 3 and Table 4.

Table 2. Awareness and perception of LSRIs and interest in scientific discoveries; sample = 230.

Variables	Code	Number	Percent	Total (number)
A1 Knowing what a RI is	0 = No	43	18.9	228[a]
	1= Yes	185	81.1	
A4 Interest in research	0 = No	29	12.7	229[b]
	1= Yes	200	83.3	
A6 Importance of funding RI	1= Useless	0	0	230
	2 = Insignificant	6	2.6	
	3 = Important Enough	38	16.5	
	4 = Important	100	43.5	
	5 = Very Important	86	37.4	
B1 Having heard about LHC	0 = No	118	51.3	230
	1 = Yes	112	48.7	
B3 Having heard about Higgs boson	0 = No	58	25.2	230
	1 = Yes	172	74.8	
B5 Having visited the CERN	0 = No	217	94.3	230
	1 = Yes	13	5.7	

Question A1: Do you know what a research infrastructure is?
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 B3: Did you ever hear of "Higgs boson"?
Question B5: Have you ever been to the CERN?
[a] 2 observations are missing;
[b] 1 observation is missing;

Table 3. Results of the question A2: Among those listed below, what is, according to you, a RI?

Item	Number of ticks
Astronomical observatory	192
Particle accelerator	159
Software and data elaborations	62
Database and Archives	62
Library	59
Planetarium	57
Telescope	42
Computer	32

Note: multiple-answer question

Table 4. Results of the question A5: If you are interested in scientific discoveries, or in research more in general, what are your sources of information?

Item	Number of ticks
On-line news	170
TV	109
Specialised magazines	62
Other	14
Radio	6

Note: multiple-answer question

The majority of respondents (81.1%) declare that they were aware of what a RI is. Multiple options were possible in identifying a RI. The option related to a particle accelerator was chosen by 159 (70%) students (Table 3); 200 (83.3%) respondents said that they were interested in scientific discoveries; online news was selected by 170 students (74%) as source of information (Table 4).

Respondents were initially asked about their view about the importance of funding RIs on a qualitative scale. Table 2 shows that 186 (81%) interviewed think that funding RIs is important or very important, 38 (16.5%) think that is fairly important, and 6 (2.6%) chose the options "Useless or Insignificant".

About 49% of the sample (112 respondents) had heard about LHC, 74.8% (172 respondents) about the Higgs boson; in contrast only 13 respondents (5.7%) visited CERN. The latter information is important, being the CERN at a travel distance of around 4 hours from Milan by train and often targeted for visits by high schools. Thus, we have indirect evidence that this sample is not particularly exposed to previous direct information on the LHC, hence all the information students have was based on exposure to the media or on the summary information distributed during the experiment.

Table 5 reports statistics related to WTP when asked according to the referendum-like approach. The percentage of '*yes*' and '*no*' is presented for each offered bid to respondents. We expect that the higher the bid, the lower the percentage of '*yes*' is. Table 5 shows that no respondents rejected the first bid (EUR 1), 5% rejected the second bid (EUR 2), 18% rejected the third bid (EUR 5) and 21% rejected the forth bid (EUR 10). At the bid EUR 15 the percentage of '*no*' reduces rather than increasing; in contrast and as expected, at bid EUR 30 it increases again. Although this distribution is not perfectly smooth (that is the reason why we adopt the pooling adjacent violators algorithm) overall, in our experiment the percentage of WTP '*yes*' is a fairly well behaved distribution.

Table 5. Response rates to offered bids; sample = 230

	WTP	
Bid (EUR)	Yes (1)	No (0)
1	100%	0%
2	95%	5%
5	82%	18%
10	79%	21%
15	81%	19%
30	73%	27%

On the question that includes WTP motivation, respondents stated different reasons, which are shown in Table 6 based on their importance. Inspection of the answers suggest quite generic motivations for giving, without a preference for one statement against another one. Differently, among respondents who rejected the offered bid, the most quoted options were "I cannot afford to pay any amount of money", "the research activity at the HC has no value for me" and finally " I am sceptic about the possibility that the LHC will achieve its objectives". They are all valid reasons to reject the bid offered, so no protest bids were identified.

Table 6. Reasons of respondents' WTP for the research activity at LHC

Motivation	Number of ticks
The LHC is a useful machine to better understand the universe and the origin of mankind	134
I think it is a good thing to contribute to basic research according to my availability of money	128
Investing in research is necessary so that next generation may benefit from new discoveries	120
The LHC is a useful machine to achieve different objectives, beyond particle physics	72
The research at LHC is worth to me at least as the offered bid	64
Other	9

Note: multiple-answer question

Table 7 presents the results of the logit model as defined by equation (1). Model 1 includes the bid, the family income and demographic characteristics. Model 2 is extended by including variables expressing attitude towards research. Model 3 leaves out the variables expressing attitude towards research and plugs in variables related to the awareness and knowledge about research activity at LHC. The full model is presented in Column 4. The estimated coefficient of the bid, which is the most important explanatory variable of probability of WTP, was found statistically significant in each specification at 1% level with the expected negative sign. This indicates that the probability of WTP '*yes*' decreases (increases) as the price of offer increases (decreases). The estimated coefficient of income variable was found statistically significant at both 5% and 1% level at the highest categories with respect to the lowest category (< EUR 1,000) and the sign was positive as expected. The finding suggests that the probability of WTP '*yes*' increases as the income increases. Age is not statistically significant. Conditional to our sample, this is not a surprising results since 91% our respondents are aged between 20 and 25. The variable "Male" shows no statistical significance as well, with negative sign in contrast with the existing literature on WTP for science and technology. The coefficients on "A4 Interest in Research" and "A6 Importance of funding RI" are significant at the 10% and 1% level respectively, with the expected positive sign (Model 2) meaning that judging funding RIs important increases the probability of WTP '*yes*'. The coefficient on "A2 Particle accelerator" is statistically significant at 1% level (Model 3) and 5% level (Model 4) and the sign is positive. Therefore, being aware of what a RIs is, increases the probability of being willing to pay for its research activity. In line with the scope tests suggested by Heberlein et al. (2005), these results support the idea that behavioural intentions, as the willingness to pay for science, are influenced by attitudinal and cognitive dimensions towards this pubic good (Sanz-Menéndez et al., 2013).

The alternation of negative and positive signs and/or absence of statistically significance on the remaining variables related to having heard about LHC or visited CERN are caused by the strong collinearity among them. For instance, the Spearman correlation coefficient between the variable "B5 Having visited CERN" and the variables "B1 Having heard about LHC" Higgs boson" and "B3 Having heard about Higgs boson" is higher than 0.60 in both cases and statistically significant at 5% level.

The results reveal that about 87% of respondents were correctly allocated to predicted WTP either '*yes*' or '*not*' in the models, indicating a relatively good fit to the data.

We test the same specifications (unreported regressions) by using the personal income rather than the family income. The availability of personal income shows positive sign but never results statistically significant in explaining the probability of a WTP '*yes*'. This was likely due to the lack of sufficient variability in this variables since only a low share of students in our sample (20%) earned an own income. We also test a further specification including a dummy variable discriminating the year in which the experiment was carried out. We found this dummy never statistically significant suggesting that no differences in WTP responses exist between students surveyed in 2016 and those surveyed in 2017. This points to robustness of the results across different cohorts of students.

Table 7. Results of logit model for the existence value of discovery potential at the LHC

	Model 1	Model 2	Model 3	Model 4
BID	-0.05***	-0.07***	-0.05***	-0.07***
	(0.02)	(0.02)	(0.02)	(0.02)
C6 Family income				
1,000 - 3,000	1.85**	1.73*	2.00**	1.95**
	(0.99)	(0.99)	(1.00)	(1.07)
3,000 – 5,000	2.14**	1.87**	2.47**	2.22**
	(1.02)	(0.99)	(1.08)	(1.10)
> 5,000	2.29**	2.46**	2.57**	2.74***
	(1.12)	(1.06)	(1.09)	(1.08)
C1 Age	0.03	-0.03	0.04	-0.01
	(0.07)	(0.05)	(0.06)	(0.05)
C2 Male	-0.41	-0.60	-0.54	-0.57
	(0.40)	(0.44)	(0.46)	(0.48)
C8 Household size	-0.23	-0.34	-0.24	-0.22
	(0.54)	(0.55)	(0.52)	(0.57)
A1 Knowing what a RI is			0.07	-0.41
			(0.53)	(0.59)
A2 Particle accelerator			1.29***	1.15**
			(0.48)	(0.47)
A4 Interest in research		0.77*		0.82*
		(0.47)		(0.50)
A6 Importance of funding RI		1.07***		1.09***
		(0.33)		(0.34)
B1 Having heard about LHC			-0.35	-0.63
			(0.48)	(0.47)
B5 Having visited CERN			-0.63	-0.55
			(0.86)	(0.76)
Constant	0.57	-2.32	-0.37	-3.41
	(2.05)	(2.09)	(1.88)	(2.13)
Observations	212	212	212	212
McFadden's R2	0.10	0.22	0.15	0.26
% of correct predictions	86%	87%	87%	88%
Log Likelihood	-78.3	-67.6	-73.7	-67.0
Likelihood ratio test	15.6	24.2	25.2	27.8

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively. The Spearman correlation coefficient between the variable "B3 Having heard about Higgs boson" and "B1 Having heard about LHC" is 0.50 significant at 5%; so the former variable was not used in Model 2 and Model 4.

The expected value of truncated mean WTP, which represents the "existence value" of basic research at LHC was calculated by numerical integration, ranging from 0 to maximum bid (Equation 2) after parameters from logit models were estimated. The coefficients estimated in Model 4 were used to determine the mean WTP, leading to a value of EUR 28 per person annually according to the following formula:

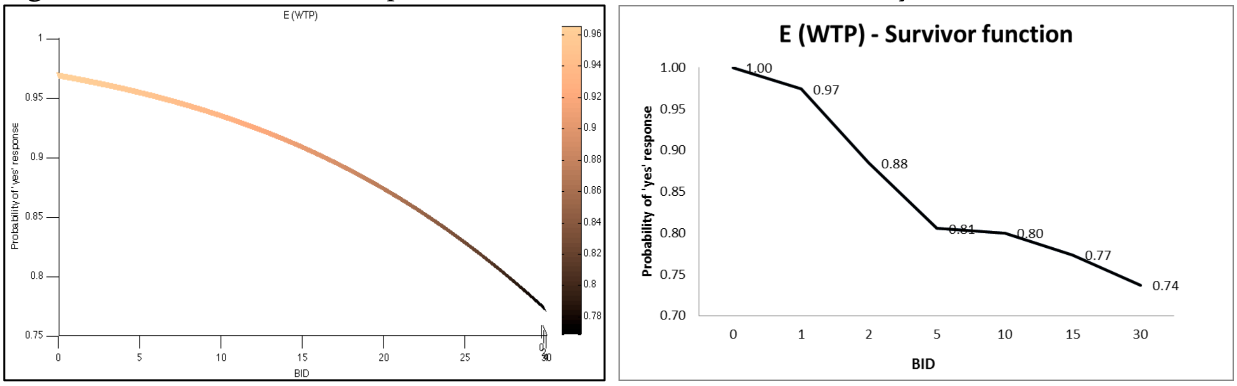
$$E(WTP) = \int_0^{30} [1 + \exp(-(7.2 - 0.07))]^{-1}\, \delta A = \text{€ } \mathbf{28} \qquad (6)$$

As said above, the non-parametric estimations require only minor theoretical restrictions such as weak monotonicity. Pool adjacent violator algorithm estimate for the mean (WTP), Equation (5), is:

$E(WTP) = \sum_{j=0}^{J} \hat{S}(A_j)[A_j - A_{j-1}] =$ **€ 23** per person annually.

This figure can be compared with the parametric estimate. Consistent with the findings in the majority of CV literature, and more specifically in Carson et al. (2003) and Haab and McConnell (1997), we found the non-parametric estimate more conservative than the parametric one. Figure 1 shows the parametric (on the left side) and non-parametric (right-side) probability curve. The horizontal axis is represented by the bid amount and the vertical axis by the estimated probability of a '*yes*' response.

Figure 1. Parametric and non-parametric WTP for the research activity at the LHC.



5. Concluding remarks

This paper reports an exploratory attempt to elicit the individual preferences expressed in monetary form for basic science by involving a sample of respondents in a classroom laboratory. The interest of such an experimental approach lies in the fact that scientific knowledge is often a pure public good, funded by governments who need to guess how much they should spend to support its production. Ultimately, all citizens fund the research through taxation. Indeed, Big-Science projects are mostly funded by governments or international organisations such as CERN, which in turn is entirely funded by transfers by its Member States. Our experiment was carried out at University of Milan by interviewing a sample of 230 undergraduates in a non-science related curriculum and submitting them a CV-like survey used to elicit an individual's WTP for discovery potential at LHC. The survey results reveal a mean WTP ranging from EUR 23 to 28 per person annually obtained by using both parametric and non-parametric estimators which is of comparable size with respect to previous findings about the non-use values of some cultural and environmental goods. For instance, the average annual WTP for the Royal Theatre in Copenhagen was found to be EUR 27 per person by Hansen (1997); while Thompson et al. (2002) found an average annual WTP for Arts ranging from USD 6 to 27 per households. In the field of environmental economics, Amirnejad et al. (2006) estimated an average annual WTP for the north forests of Iran of about EUR 30 per households and Carson et al. (2003) found that for preventing damages from another Exxon Valdez type oil spill people were willing to pay a median lump-sum WPT amounting to about USD 30.

In a different perspective one can compare the results of our survey with the actual monetary contribution through taxation from Italy to CERN budget, hence to the LHC. In 2017, the Italy's contribution to CERN amounted to about EUR 100 million (10% of the total amount of contributions by Member States), meaning that each Italian taxpayer pays about EUR 2 per year to CERN. However, as we are going to discuss below, comparing our findings with the actual average tax burden of the average Italian citizen is not appropriate for several reasons.

What do we learn from this pilot experiment, which is entirely novel in the literature?

An obvious issue is that one should be able to design the experiment for a representative sample of taxpayers. This, *per se,* is not impossible, as social attitudes (including on science) are regularly performed with statistically representative samples of the population (see for instance

European Commission, 2014). The main difficulty however, is that while research on social attitudes often tends to ask generic questions, here it is of essence to elicit a WTP for a specific project, as it is needed in a cost-benefit analysis setting. This poses a special problem as the previous knowledge of the discovery potential of a specific RI, or even that such project exists, is an information not usually available to the general public, or unevenly available through exposure to the media. Moreover, the nature of such information is unavoidably very superficial for the average citizen, who certainly cannot grasp the scientific importance of knowing that the Higgs boson actually exists. In principle, one should then control for the previous exposure of respondents to outreach of science news in the media in order to be sure that the sample of respondents is not affected by sample bias over a crucial dimension of individual preferences. This is clearly revealed by our experiment which shows that previous knowledge about what is a RI is strongly correlated to the elicited WTP.

The problem is not unknown in environmental cost-benefit analysis, as surveyed respondents can be assumed to fully understand, for example, the implications for biodiversity in a given area of a specific project. Given the importance of this issue, it would be advisable to add to the usual demographics of the sampling strategy a set of variables capturing attitudinal and cognitive information related to the project under evaluation.

The second important point raised by our approach is in terms of the way to elicit the WTP in terms of opportunity cost. While in our experiment it was clearly stated that virtual giving to the LHC project was to be set against decreasing consumption on other items, behavioral economics often relies on the involvement of actual money (Chaudhuri, 2008). Recurring to an experimental setting where giving of real and possibly earned income is involved is obviously attractive, but a trade-off arises. The experimental economics literature is typically based on small scale laboratory experiments with students (as in our case) but it does not aim then to expand to a population of taxpayers the empirical analysis, as it usually would be too costly and would pose a number of additional design problems. This unfortunately means that laboratory experiments with actual money have very limited implications for (science) policy. However, future research may try to replicate our experiment in a laboratory setting involving actual, possibly earned money, in order to highlight some qualitative issues arising in this area.

Perhaps more important for future research, while still sticking to the CV approach, is to check the robustness of results when alternatives are given. This would lead to the complication of adding bids for competing scientific or non-science projects, adding information in terms of consumer choice but also introducing some risks of distorting elicited preferences just because of the specific set of suggested alternatives.

With all these reservations, it seems worth exploring ways to empirically estimate the non-use value of fundamental research. Our contribution is to suggest that this study may offer valuable information that can be useful from both the science policy viewpoint and academic research. In order to be funded, curiosity-driven science has to continuously justify its existence. Eliciting the willingness to pay for large scale RIs may suggest to governments to what extent people (at least the most educated segment of the population) have preferences for public funding of science even if there is no-use in view of the potential new knowledge. For policy makers this evidence would represent a step forward in relation to the longstanding political disputes in research funding on how to get more economic and social value for investments in research and innovation (NASA, 2015; Science|Business, 2015). In fact, the non-use value of RIs adds to their use value and may play in favour of economic benefits when costs and benefits of RIs are put at stake, and would avoid a bias in favour of the research promising more direct economic returns.

In terms of academic research, the paper contributes to the literature on public goods by an assessment of the non-use value of the discovery potential of a large RI, as far as we know an entirely new field in cost-benefit analysis, which would greatly enlarge the perspective of environmental and cultural economics (Del Bo et al., 2016; Florio and Sirtori, 2016; Johansson, 2016).

Additional research should target a representative sample of taxpayers in countries supporting large scale RIs (for example the CERN Member States). Moreover, the assessment of the non-use value of basic science requires the investigation in other fields as well, beyond high-energy physics. This is left to future research.

Acknowledgments:

The authors are grateful to Gelsomina Catalano (UNIMI and CSIL), Chiara Pancotti (UNIMI and CSIL) and Donatella Cheri (CSIL) for research assistance. This work has been carried out in the framework of the FCC study collaboration agreement KE3044/ATS. The findings, interpretations and conclusions presented in this article are entirely those of the authors and should not be attributed in any manner to CERN or other institutions. Any errors remain those of the authors.

References

ALBERINI A., KANNINEN B., and CARSON R. T., 1997, 'Modelling Response Incentive Effects in Dichotomous Choice Contingent Valuation Data', *Land Economics,* 73 (3), 309-324.

AMIRNEJAD H., KHALILIAN S., ASSAREH M. H. and AHMADIAN M., 2006, 'Estimating the Existence Value of North Forests of Iran by Using a Contingent Valuation Method', *Ecological Economics*, *58*(4), 665-675.

AMPONIN J. A., BENNAGEN E., HESS S. and DELA CRUZ J., 2007, 'Willingness To Pay For Watershed Protection by Domestic Water Users in Tuguegarao City, Philippines', *Poverty Reduction and Environmental Management (PREM), Working Paper 07/06 ASEAN Center for Biodiversity*, 2007-06.

AYER M., BRUNK H. D., EWING G. M., REID W. T. and SILVERMAN E., 1955, 'An Empirical Distribution Function for Sampling with Incomplete Information', *The annals of mathematical statistics*, *26*(4), 641-647.

ARROW K., 1962, 'Economic Welfare and the Allocation of Resources for Invention', In The rate and direction of inventive activity: Economic and social factors pp. 609-626, National Bureau of Economic Research, Princeton: Princeton University Press.

ARROW K., SOLOW R. S., LEARNER E., PORTNEY P., RODNER R. and SCHUMAN H., 1993, 'Report Of The Noaa-Panel On Contingent Valuation', *Federal Register*, 58(10): 4601-4614.

BATEMAN I. J., CARSON R. T., DAY B., HANEMANN M., HANLEY N., HETT, T. and PEARCE D. W., 2002, *Economic Valuation with Stated Preference Techniques: A Manual*, Cheltenham: Edward Elgar Publishing Ltd.

BATTISTONI G., GENCO M., MARSILIO M., PANCOTTI C., ROSSI S. and VIGNETTI S., 2016, 'Cost–benefit analysis of applied research infrastructure. Evidence from health care', *Technological Forecasting and Social Change*, *112*, 79-91.

BISCARI C., 2012, 'CNAO Commission and Operation', Frascati (Rome): Italian National Physics Laboratories – National Institute of Nuclear Physics (LNF – INFN).

CARSON R. T., 1985, 'Three Essays on Contingent Valuation (Welfare Economics, Non-Market Goods, Water Quality)', PhD Thesis, Department of Agriculture and Resource Economics. University of California, Berkeley.

CARSON R. T., MITCHELL R. C., HANEMANN M., KOPP, R. J. PRESSER S. and RUUD, P. A., 2003, 'Contingent Valuation and Lost Passive Use: Damages From the Exxon Valdez Oil Spill', *Environmental and resource economics*, *25*(3), 257-286.

CATALANO G., FLORIO M., and GIFFONI, F., 2016, 'Willingness To Pay for Basic Research: A Contingent Valuation Experiment on the Large Hadron Collider', *arXiv preprint arXiv:1603.03580*.

CHAUDHURI A., 2008, *Experiments in economics: playing fair with money*, London: Routledge.

COOPER J. C., 2002, 'Flexible Functional Form Estimation of Willingness To Pay Using Dichotomous Choice Data', *Journal of Environmental Economics and management*, *43*(2), 267-279.

CROOKER, J. R. and HERRIGES J. A., 2004, Parametric and Semi-Nonparametric Estimation of Willingness-To-pay in the Dichotomous Choice Contingent Valuation Framework', *Environmental and resource economics*, *27*(4), 451-480.

DEL BO C. F., FLORIO M. and FORTE S., 2016, 'The Social Impact of Research Infrastructures at the Frontier of Science and Technology: The Case of Particle Accelerators', *Technological Forecasting and Social Change*, (112), 1-3.

DUFFIELD J. W. and PATTERSON D. A., 1991. 'Inference and Optimal Design for a Welfare Measure in Dichotomous Choice Contingent Valuation', *Land Economics*, 225-239.

EUROPEAN COMMISSION, 2014, 'Special Eurobarometer 419. Public Perception of science, research and innovation, October 2014', Brussels: European Commission. Available from: http://ec.europa.eu/public_opinion/archives/ebs/ebs_419_en.pdf

EUROPEAN COMMISSION, 2016, 'Science and Policy Making: towards a new dialogue. The 2nd International Network for Government Science Advice Conference 29-30 September 2016, Brussels. http://ec.europa.eu/research/conferences/2016/ingsa2016/index.cfm

FILIPPINI, M., MASIERO, G. and MEDICI, D., 2014, 'The Demand for School Meal Services by Swiss Households', *Annals of Public and Cooperative Economics*, 85(3), 475-495.

FLORIO M., 2014, '*Applied Welfare Economics: Cost-benefit Analysis of Projects and Policies',* London: Routledge.

FLORIO, M. and SIRTORI, E., 2016, 'Social Benefits and Costs of Large Scale Research Infrastructures', *Technological Forecasting and Social Change*, 112, 65-78.

FLORIO, M., FORTE, S. and SIRTORI, E., 2016, 'Forecasting the Social Impact of the Large Hadron Collider: A Cost-Benefit Analysis to 2025 and Beyond', *Technological Forecasting & Social Change,* 112, 38-53.

GIUDICE G.F., 2010, *A Zeptospace Odissey*. *A Journey into the Physics of the LHC*, Oxford: Oxford University Press.

GRAZHDANI D., 2013, 'Applying Contingent Valuation Survey to Assess the Economic Value of Restoring Ecosystem Services of Impaired Rivers: A Case Study in Transboundary Buna River Region, Albania', *International Journal of Innovative Research in Science, Engineering and Technology*, *2*(10), 5115-5123.

GREEN D., JACOWITZ, K. E., KAHNEMAN D. and MCFADDEN D., 1998, 'Referendum Contingent Valuation, Anchoring, and Willingness To Pay for Public Goods', *Resource and Energy Economics*, 20(2), 85-116.

HAAB T. C. and MCCONNELL, K. E., 1997, 'Referendum Models and Negative Willingness To Pay: Alternative Solutions', *Journal of environmental economics and management*, *32*(2), 251-270.

HANEMANN W. M., 1984, 'Welfare evaluations in contingent valuation experiments with discrete responses', *American journal of agricultural economics*, *66*(3), 332-341.

HANSEN T. B., 1997, The Willingness-To-Pay for the Royal Theatre in Copenhagen as a Public Good', *Journal of cultural economics*, 21(1), 1-28.

HEBERLEIN T. A., WILSON M. A., BISHOP R. C., AND SCHAEFFER, N. C., 2005, 'Rethinking the Scope Test as a Criterion for Validity in Contingent Valuation', *Journal of Environmental Economics and Management*, *50*(1), 1-22.

HINDRIKS J. and MYLES G. D., 2013, '*Intermediate Public Economics*', Cambridge: MIT press.

HUANG J. C., NYCHKA D. W. and SMITH V. K., 2008, 'Semi-Parametric Discrete Choice Measures of Willingness To Pay', *Economics Letters*, *101*(1), 91-94.

JOHANSSON P. O., 2016, 'On Lessons from Energy and Environmental Cost–Benefit Analysis. *Technological Forecasting and Social Change*, 112, 20-25.

JOHANSSON P.O. and KRISTRÖM B., 2015, *Cost-Benefit Analysis for Project Appraisal*, Cambridge, UK: Cambridge University Press.

JOHNSTON R. J., BOYLE K. J., ADAMOWICZ, W., BENNETT J., BROUWER R., CAMERON T. A., HANEMANN W.M., HANLEY N., RYAN M., SCARPA R., TOURANGEAU R. AND VOSSLER C.A., 2017, 'Contemporary Guidance For Stated Preference Studies', *Journal of the Association of Environmental and Resource Economists*, 4(2), 319-405.

KRISTROM B., 1990, 'A Non-Parametric Approach to the Estimation of Welfare Measures in Discrete Response Valuation Studies', *Land Economics*, 66(2), 135-139.

LI Q., 1996, 'Nonparametric Testing of Closeness between Two Unknown Distribution Functions', *Econometric Reviews,* 15(3), 261-274.

MCFADDEN D., 1994, 'Contingent Valuation and Social Choice', *American Journal of Agricultural Economics*, *76*(4), 689-708.

MITCHELL R. C. and CARSON R. T., 1989, '*Using Surveys to Value Public Goods: The Contingent Valuation Method*', Washington D.C: The Johns Hopkins University Press for Resources for the Nature.

NASA , 2015, 'NASA KNOWLEDGE 2020: Imaging the Future of Knowledge Services, on line edition. Washington, DC: National Aeronautics and Space Administration.

OECD, 2002, 'Frascati Manual 2002: Proposed Standard Practice for Surveys on Research and Experimental Development', Paris: Organisation for Economic Co-operation and Development.

REUTERS, 2016, 'Nuclear Fusion Reactor ITER's Construction Accelerates as Cost Estimate Swells', Reuters Article. Available at http://www.reuters.com/article/us-france-nuclear-iter-idUSKCN1271BC

ROMER P. M., 1986, 'Increasing Returns and Long-Run Growth', *Journal of political economy*, *94*(5), 1002-1037.

ROSSI L., 2017, 'Introduction to the HL-LHC Project', Presentation held at CERN on February 2, 2017. Available from: https://indico.cern.ch/event/606369/contributions/2443838/attachments/1405928/2148075/HL-LHC_Introduction_Rossi_2feb2017.pdf

SANZ-MENÉNDEZ L., VAN RYZIN G. G. and DEL PINO E., 2013, 'Citizens' support for government spending on science and technology', *Science and Public Policy*, 41(5), 611-624.

SCIENCE|BUSINESS, 2015, 'BIG SCIENCE: What's It Worth? Special Report produced by the support of CERN, ESADE Business School and Aalto University, Brussels: Science|Business Publishing Ltd.

STIGLITZ J. E., 1999, 'Knowledge as a Global Public Good', *Global public goods*, *1*(9), 308-326.

THOMPSON E., BERGER M., BLOMQUIST G. and ALLEN, S., 2002, 'Valuing the Arts: A Contingent Valuation Approach', *Journal of Cultural Economics*, 26(2), 87-113.

TURNBULL B. W., 1976, 'The empirical distribution function with arbitrarily grouped, censored and truncated data', *Journal of the Royal Statistical Society. Series B (Methodological)*, 290-295.

WATANABE M. and ASANO K. , 2009, 'Distribution Free Consistent Estimation of Mean WTP in Dichotomous Choice Contingent Valuation', *Environmental and Resource Economics*, *44*(1), 1-10.

ANNEX I - Questionnaire

CONTINGENT VALUATION
OF RESEARCH INFRASTRUCTURES

INFORMATION IN COMPLIANCE WITH D.LGS. 196/2003

For the purposes and for the effects of Art. 13 of Legislative Decree 196/2003 containing "Personal Data Protection Code" and subsequent amendments, we inform you that the personal data you provide during the following experiment will be subject to manual and / or electronic processing in the respect of suitable data security measures, and only for the purposes of economic and statistical analysis.

☐ *I authorize the processing of my personal data in compliance with Legislative Decree 196 of 30 June 2003.*

SECTION A	
A.1. Have you ever heard about research infrastructures before this survey?	□ 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 □ Particles Accelerator □ Library □ Computer □ Astronomical Observatory □ Planetarium
A.3. Please, provide an example of research infrastructure that you know or you have visited	
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. How do you rate the importance of funding research infrastructures**?**	□ Insignificant □ Useless □ Important enough □ Important □ Very important
A.7. Please, explain your choice at question A.6.	

LARGE HADRON COLLIDER (LHC)

What is the LHC?

The Large Hadron Collider (LHC) is the biggest and most powerful particle accelerator ever built. It can accelerate adrons (heavy protons and iones) up to 99,9999991% of speed of light and make them collide afterwards, currently reaching an amount of energy, in the mass centre, of 8 teraelettronvolt (it is expected that, in 2015, this energy will reach near 14 teraelettronvolt, which is the full capacity of the infrastructure). It's located at the CERN of Geneva and is built inside an underground 27 km-long tunnel located on the border between France and Switzerland, in a region included between the Geneva airport and the Giura mountains, originally excavated to build the Large Electron-Positron Collider (LEP). The tunnel is located at an average depth of 100 meters.

It is formed by about 2,000 superconductive magnets, maintained at a temperature of -271 °C. The low temperature serves to create in the magnets the phenomenon called 'superconductivity': 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 to caverns where the tunnel widens in large experimental halls. In these stations there are four principal experiments of particle physics: ATLAS (A Toroidal LHC Apparatus), CMS (Compact Muon Solenoid), LHCb (LHC-beauty) and ALICE (A Large Ion Collider Experiment). Those enormous facilities consist in a large number of detectors that use different technologies and operate around the pint where the beams collide. During collisions, thanks to the transformation of a part of the high energy in mass, a very large amount of particles is produced whose properties are measured by the detectors. The two smallest detectors are TOTEM and LHCf.

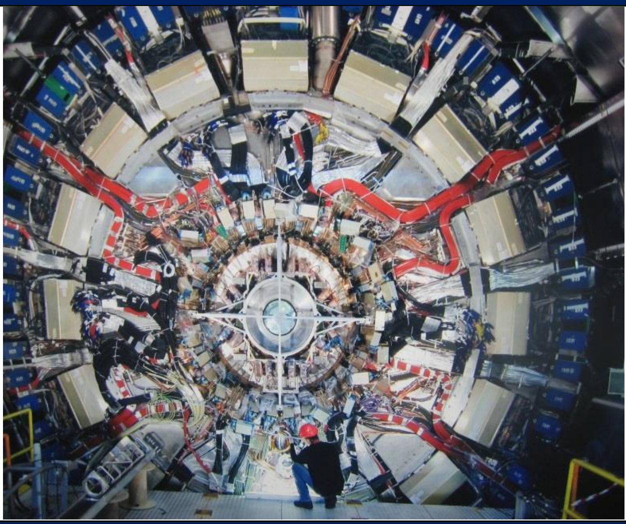
The entry into operation of LHC, originally scheduled for the ned of 2007, took place on September 10, 2008. Italy participates in the LHC project within the context of its contribution to CERN as member state (the division of CERN budget between member Countries is based on the GDP).

<u>What is the purpose of LHC and its single experiments?</u>

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

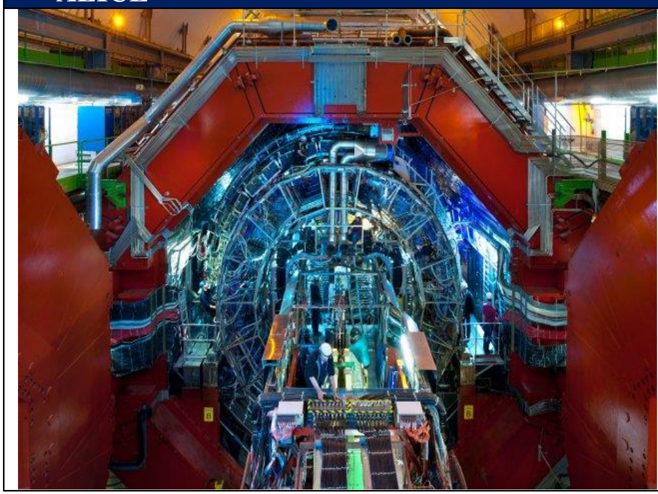
- **ATLAS e CMS**: revealed the Higgs Boson and deal with the research of super-symmetry.
- **ALICE:** works on plasma of Quark and the gluons, a state of matter existed in the first moments after the Big Bang.
- **LHC-b**: studies how asymmetry between matter and antimatter was created.
- **LHC-f**: it is the smallest experiment and verifies theories on cosmic rays.
- **TOTEM:** Measures the probability and the impact modalities between protons in the LHC.

ATLAS



CMS

ALICE



LHC-b

In future, LHC may also discover the existence of super-symmetrical particles and push us to think that universe is not made of only four dimensions as we perceive (right-left, up-down, backforth, plus the time dimension) but by many other dimensions invisible to us, rolled up on themselves. LHC may help us understand: Why the matter we are made of is so stable during the time; Why universe is expanding faster than expected; Why universe seems to be made by a 95% of something we do not see and we do not know, but acts on galaxies and therefore exists.

SOURCE: *Wikipedia (28/05/2014)*

SECTION 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 "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 the CERN?	□ YES □ NO

PAYING FOR RESEARCH INFRASTRUCTURES AND FUNDAMENTAL RESEARCH

The LHC is funded by CERN Member States through taxes. Specifically, all taxpayers coming from CERN Member States contribute to fund the LHC through a share of taxes they pay to their respective governments. Such taxes allow the LCH to continue its activity in the future.

B.6. Suppose you (or your family) are asked to contribute for the activity of the LHC. Bear in mind that such contribution will decrease your budget (or that of your family) for other expenses or consumption. Would you willing to provide every year an economic contribution of € ____ to fund the research activity of the LHC?

(Please select only one option)

□ YES □ NO

B.7. What is the maximum you would pay each year to fund the research activity of the LHC?

(Please insert the amount in euro)

€ _____________

Answer question B.8. only if you said you would not pay anything (you selected "No" to the question B.6 and wrote € 0 to question B.7). Otherwise go to question B.9.

B.8. What are the main reasons you said you would pay zero?

(For this question it is possible to choose multiple answers)

□ The activities at LHC are not worth anything to me;
□ The LHC is an useless machine whose construction could have been avoided;
□ The LHC is a dangerous machine for the risk of nuclear accidents;
□ I can't afford to pay ay this time;
□ I am opposed to any new governments programs;
□ I do not think the LHC would achieve its objectives;
□ The LHC is a machine that affects only physicians' and scientists' world, so it unfair to expect me (or my family) to pay for the LHC

□ Other Reasons (Please explain):
____
____
____

B.9. Why would you pay your amount?

(For this question it is possible to choose multiple answers)

□ The activities at LHC are worth at least this much to me;
□ The LHC is a useful machine for experiment with protons' acceleration which can be used for different purposes;
□ The LHC is an useful machine to increase our knowledge of the universe and the origin of mankind;
□ I feel a duty towards next generations which may benefits from new discoveries;
□ To pay my fair share to developments in fundamental research;
□ Other Reasons (Please explain):
____
____
____

SECTION C	
C.1. What is your age?	__________ # YEARS
C.2. Sex:	□ M □ F
C.3. Your city	
C.4. What is your educational background (pre-university):	□ Scientific □ Classical □ Technical □ Other (please specify):
C.5. What was your average score during your pre-university studies?	□ 100 cum laude □ 100 □ 90 – 99 □ 80 – 89 □ 70 – 79 □ 60 – 69

C.6. In which of the following categories does <u>your family monthly gross income</u> (before tax) fall?	□ up to 999 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? If Yes, please insert the monthly amount (before tax)	□ YES € ____________ □ NO
C.8. What is the <u>number of components</u> of your family (including parents, brothers/sisters):	□ 1-2 □ from 3 to 5 □ more than 5