The Value of Open Science at CERN: An Analysis Based on a Travel Cost Model

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Abstract Open science is a fundamental root of the European Organization for Nuclear Research, known by its acronym CERN. This international organization, located between Switzerland and France, has distinguished itself since its inception by sharing its discoveries, innovative technologies, and the information generated by its most ambitious project, the Large Hadron Collider (LHC) so that researchers around the world and society can benefit from the data gathered and the knowledge created. One of the main characteristics of the organization is the possibility to freely visit the particle accelerators and the experiments at these machines. On these occasions, visitors can meet the scientists and learn directly from them about the organization, its discoveries, and its daily activities. This study is one of the few assessing the economic value of these initiatives. It is based on a survey using a sample size of 900 visitors to CERN during one calendar year. Results from a travel cost application show that visitor would be willing to pay a total on average at least 0.72 € over the cost of the trip per person, owing to the experience and knowledge gained during their visit to the infrastructure.

Keywords CERN · LHC · Travel cost method · Willingness to pay · Consumer surplus · Open science · Economic impact · Social impact

1 Introduction

CERN, the European Organization for Nuclear Research, is one of the world's most prestigious research institutions in particle physics. Founded in 1954, CERN is situated at the convergence of Switzerland and France, with a mission to decipher the fundamental laws that govern the universe. Employing advanced particle accelerators

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and colliders, notably the powerful Large Hadron Collider (LHC), CERN delves into the conditions of the early universe, providing insights into its inception. The LHC, described by Professor Brian Edward Cox in a TEDx talk (2008) as "the biggest scientific experiment ever attempted", spans 27 km and hosts four main experiments: Atlas, CMS, Alice, and LHCb. These experiments focus on general-purpose detection, heavy-ion physics, and the investigation of matter–antimatter differences. CERN's impactful contributions include the development of the theory underlying the Higgs boson [1], confirmed in 2012; the translation of particle physics technologies into cancer treatment (hadron therapy) [2]; and Medipix detector chips [3], enabling high-definition imaging of human tissues.

Educational trips to CERN are a valuable opportunity for students and educators to learn about cutting-edge physics research, explore the world of particle physics, and gain insights into the workings of one of the most advanced scientific facilities on the planet. CERN is where Tim Berners-Lee and Robert Cailliau developed the World Wide Web in 1989. The Web [4] was originally developed as a system that allowed physicists worldwide to exchange information freely in a decentralized, open, and scale-free manner. The underlying communication protocols and software were made freely available to the public in 1993 so that anyone with a server and a browser could use it and continue to develop the infrastructure. This discovery made CERN and its most audacious project, the Large Hadron Collider (LHC), one of the well-known names in the "open science" movement.

The open science policy is not only conducted by sharing information over the Internet. There are numerous ways in which information can be disseminated, both to the scientific community and society at large. In the case of CERN, programs for students and professors, subcontracting of research infrastructure work to companies in member countries, or work contracts promote research and learning to all who wish to benefit. Another means of disseminating knowledge is CERN's visit program. CERN has been open to the public since 1958, i.e., only four years after its creation. Since its beginnings, it has evolved its way of engaging laypeople and has become increasingly accessible. Numerous studies and organizations such as UNESCO [5] and the OECD [6] have endeavored to show that the "open science" movement promotes free access to scientific research to enrich society.

The study presented in this article aimed to capture a part of the total social impact of CERN a global reference for "Open Science", in monetary terms by measuring the economic value of the socio-economic impact potentials of on-site visitors. It sheds light on this question by examining a subset of the economic values created that are directly related to CERN's research program. The impact potential has been estimated based on an anonymous survey administered to different class visitors during one calendar year. The data have been examined methodically and in detail, distinguishing between registered and unregistered visitors. The goal is to obtain an estimate of the potential value of all on-site visitors based on the generalized estimated willingness to pay (WTP) by visitors to CERN between June 2018 and May 2019. The survey was administered before the closure of visits suffered by the organization due to the COVID-19 pandemic. This article proceeds as follows: Initially, we will present a comprehensive examination of the diverse impacts generated by

CERN, encompassing both scientific and social aspects. This exploration is underlined by a robust correlation, stemming from the organization's commitment to the Open Science movement. To conclude, we will describe the most relevant policy implications of our findings.

2 Impacts of CERN

The 1953 CERN convention established the principle that "all scientific findings should be easily accessible to the general public." Although the term "open" lacks a specific definition, CERN has consistently honored this commitment by generously sharing its scientific discoveries and technological advancements with the scientific community, private industry, and society at large. This dedication has led to significant advancements in scientific knowledge, firmly solidifying CERN as a stronghold of open science.

The impact of CERN's foundational principle extends across various domains aligned with its mission and discoveries. Consequently, studies examining the organization's influence have categorized their results into four primary areas: Scientific knowledge, Innovation and knowledge transfer, Training and education, and engagement of individuals not directly affiliated with the organization's core activities, considered the public audience. This broad-reaching influence underscores CERN's role as a pioneer in promoting transparency and accessibility in the realm of scientific research.

2.1 Scientific Knowledge

LHC is not the only research infrastructure that CERN operates. There are other unique facilities available to the scientific community. Some examples are:

- **The Antiproton Decelerator (AD)** [7], a machine that produces low-energy antiprotons for antimatter research.
- **The Isotope Mass Separator On-Line facility (ISOLDE)** [8], a source of low-energy beams of radioactive nuclides.
- **The Cosmic Leaving Outdoor Droplets (CLOUD)** [9], an experiment that uses a special cloud chamber to study the possible link between galactic cosmic rays and cloud formation.
- **OpenLab** [10], a platform to jointly develop and test ICT technologies with industrial partners.
- **IdeaSquare** [11], an open environment to engage creative minds in technology projects from a diverse set of academic and business backgrounds.
- **S'Cool Lab** [12], a hands-on particle physics learning laboratory for high-school students and their teachers from around the world.

- **HiRadMat** [13], a facility to study the effects of ionizing radiation for the benefit of academic and business users such as the space industry and several more.

Roughly 70% of the worldwide community of high-energy and particle physicists actively participate in institutions dedicated to exploring the fundamental principles of the natural world. According to [14], this collaborative endeavor has produced around 27,000 publications linked to Large Hadron Collider (LHC) experiments, with a significant presence in approximately 24,000 other research works. Consequently, these 24,000 publications have been cited in an impressive 862,000 additional research papers, illustrating the extensive impact and influence of collective efforts in the field.

2.2 Innovation and Knowledge Transfer

Knowledge transfer involves sharing or disseminating knowledge and contributing to problem-solving [6]. In 1988, CERN established the Industry and Technology Liaison Office to manage knowledge and innovation transfer. A year later, Timothy Berners-Lee and Robert Cailliau developed what is now commonly known as the Web. Four years after that, CERN made the underlying communications protocols and software freely available to the public. Despite the initial perception that providing such a crucial service to humanity would have minimal impact, a study by [15] estimated the global impact of the Internet to be 2.9% of world GDP, equivalent to $1,672 billion.

The extensive data flow produced by the LHC project prompted the establishment of the Worldwide LHC Computing GRID. This network facilitates the distribution of data from CERN to 11 major computing centers across Europe, North America, and Asia, which then disseminate it to 170 centers in 42 countries. Initially, raw, preprocessed, and annotated data is shared with members of the LHC experiment scientific collaborations. However, a subset of annotated data and simplified data suitable for home-programmed analysis software is later made available, with a time delay, to researchers outside of the collaborations, as well as to schools and the interested public through open-access data infrastructures. This global integration of data storage and processing centers has empowered thousands of scientists worldwide to engage with this data. The infrastructure processes an impressive 50–70 petabytes of data per year during the operation of the Large Hadron Collider (LHC) at CERN. The Worldwide LHC Computing GRID actively collaborates with entities such as the European Grid Infrastructure, the Open Science Grid, and the Nordic e-Infrastructure Collaboration.

Open science at CERN extends beyond the dissemination of information about projects conducted on the infrastructure. It encompasses more than the sharing of scientific research, as the organization has developed various tools and software to enhance day-to-day operations. These include the Zenodo virtual repository [16], the Indico meeting, workshop, and conference management tool [17], the Root data processing framework, and the Protonmail encrypted email service [18]. All these tools are freely available and compatible with any computer. Protonmail, the encrypted email service, is offered to users in different models, either for free or on a subscription basis, depending on the user's requirements.

CERN delegates a substantial portion of its work conducted at its facilities to companies located in its member countries, constituting approximately 50% of CERN's annual budget. This practice has a direct impact on the contracted companies. As illustrated by Bianchi-Streit et al. [19], CERN's economic influence can be measured by the combined increase in revenue and reduction in costs. Through a comprehensive survey involving 160 high-technology companies, the researchers found that during the period from 1973 to 1982, the adjusted utility/sales ratio was 3. This result indicates that for every Swiss franc invested by CERN in high technology, it yields three Swiss francs in economic benefits.

CERN also brings additional advantages, including knowledge transfer to scientists, engineers, and all those working in its infrastructures. This knowledge transfer extends to assisting workers and entrepreneurs in creating spin-off companies. An example of this is the establishment of nine Business Incubation Centers (BICs) in 2016 to transform CERN innovations into marketable products.

Another notable example of a spin-off is Advanced Accelerator Applications (AAA). Established in 2002, AAA emerged as a spin-off from CERN under the guidance of physicist Stefano Buono, intending to commercialize a patent developed during his tenure at CERN, alongside Nobel laureate Carlo Rubbia. Specializing within the scope of nuclear medicine, the company's product line encompasses molecular imaging diagnostics and therapeutics designed to facilitate disease assessment, monitoring, and the selection of appropriate treatments. Central to their offerings are radiopharmaceuticals, which consist of radioactive particles known as radioisotopes and are utilized in positron emission tomography (PET) and single photon emission tomography (SPECT) [20].

Advanced Accelerator Applications has effectively positioned itself as a trailblazer in the global nuclear medicine market. The company has consistently expanded its sales and international footprint by acquiring companies and laboratories, as well as fostering collaborations with institutions like Warsaw University. Currently, Advanced Accelerator Applications operates in 12 countries and maintains 29 centers across Europe and the United States. In 2018, the multinational corporation Novartis acquired Advanced Accelerator Applications for € 3.4 billion [21]. The establishment and growth of Advanced Accelerator Applications have not only had a significant economic impact on CERN but have also contributed to social progress through the company's innovative advancements in the field of nuclear medicine.

2.3 Training and Education

Training and education form integral pillars of CERN's mission. As per a 2016 study conducted by the organization, there are consistently over 2400 doctoral students enrolled at CERN at any given time, leading to the completion of approximately 600 theses annually. In the summer season, around 300 undergraduate students, representing both CERN member and non-member countries, partake in an internship program spanning between 8 and 13 weeks. Additionally, several hundred engineering, physics, and technical students engage in dedicated, long-term assignments at CERN, typically lasting about a year, allowing them to accrue valuable knowledge and innovative experience.

Since 1966, approximately 350 students have been or are currently involved in CERN's apprenticeship program. Each year, about 10 students aged between 15 and 19 embark on this comprehensive training, which includes both theoretical and practical components over about four years. The program equips them to obtain a technician diploma in their chosen field upon completion.

Reference [22] assessed the impact of CERN on the development of human capital. Their research revealed that individuals engaged in scientific high-tech projects at CERN for one to three years experience a 5–11% increase in their lifetime earnings upon entering the job market following their CERN experience. This study involved comparing the salary outcomes for students who participated in programs at CERN with those who received similar training at the university alone but did not engage in high-tech scientific projects at CERN.

Students are not the only ones who have access to programs to improve their learning skills. Teachers and faculty members, too, can improve their teaching skills by using examples from CERN's research to make their lessons more engaging. Since 2006, each year about one thousand teachers have participated in CERN's programs.[1] The impact of these teachers' programs affects not only them but also all the students who attend their classes daily.

2.4 General Audience

The development of the World Wide Web revolutionized information access for the global population, creating more efficient horizontal and vertical linkages in society. As of 2021, a study by Global Digital revealed that 59.6% of the world's population were active internet users, with 53.6% actively engaged in social media. Many individuals utilize these platforms for news consumption, exploring topics of interest, and interacting within their social circles. However, it's important to note that the substantial influence of this digital landscape is primarily dominated by a select few corporations, often referred to as the "big five FAAMG": Facebook, Amazon, Apple, Microsoft, and Google. Notably, these giants are not directly associated with CERN. It's essential to recall that the technology underpinning the internet was initially developed to meet the demands of fundamental physics research and was entirely funded by taxpayer money, thus rightfully accessible to all of humanity for free.

[1] CERN Teacher programmes. https://teacher-programmes.web.cern.ch/.

The initial assessments of the socio-economic benefits arising from CERN's diverse impact pathways linked to the Large Hadron Collider were conducted by [14]. The data on the World Wide Web (WWW) and social media usage were collected at an early stage of these technologies before they were fully integrated into society. Subsequent studies [23], have successfully assigned a monetary value to the time people spend on these various channels to learn about CERN and its research activities. The calculated monetary value for the time spent by internet users on CERN's websites and social media platforms, including YouTube, Facebook, Twitter, and Instagram, from 2007 to 2025, amounts to 2.9 billion euros (base year 2007). The impact derived from social media appears relatively modest compared to the global reach of mainstream media. This may be related to the fact that the analysis has not fully captured the additional impact generated through responses, comments on other platforms such as blogs or websites, and the dissemination of information. Therefore, the results should be interpreted as rather conservative.

CERN is committed to open public access, offering free entry year-round. The organization has established two permanent exhibitions and guided tours designed to help visitors understand its research activities, enabling them to delve into the world of particle physics and trace the origins of the universe. Additionally, certain times of the year provide the public with the opportunity to visit the underground sites of the LHC experiments, with guided tours available. CERN's records indicate that approximately 120,000 individuals visit the facility annually, including around 70,000 high school students. The study presented in this article evaluates the economic impact potential associated with visitors to CERN.

3 Assessing the Economic Impact of On-Site Visitors at CERN

CERN offers visitors two permanent exhibitions and a year-round free guided tour for those who wish to discover the cathedrals of technology housed in the organization. In the Microcosmos exhibition, visitors can take a behind-the-scenes look at the organization to discover CERN's experiments and find out what goes on inside its flagship Large Hadron Collider. In this exhibition, visitors discover the history of CERN, told by the organization's staff in interactive videos.

In 2004, the Swiss government donated the Universe of Science and Innovation building to CERN, also called the Globe because of its shape, in celebration of the organization's 50th anniversary. Since then, the building has been used as a tool for outreach and events by CERN. In this exhibition, visitors can immerse in the world of particles and discover the traces of cosmic rays, the first web server, and the main questions of today's physics. The visitor can also enjoy a show about the origins of the Universe.

A guided tour is offered for all visitors to experience first-hand what the first accelerator built by CERN looks like (Figs. 1 and 2).

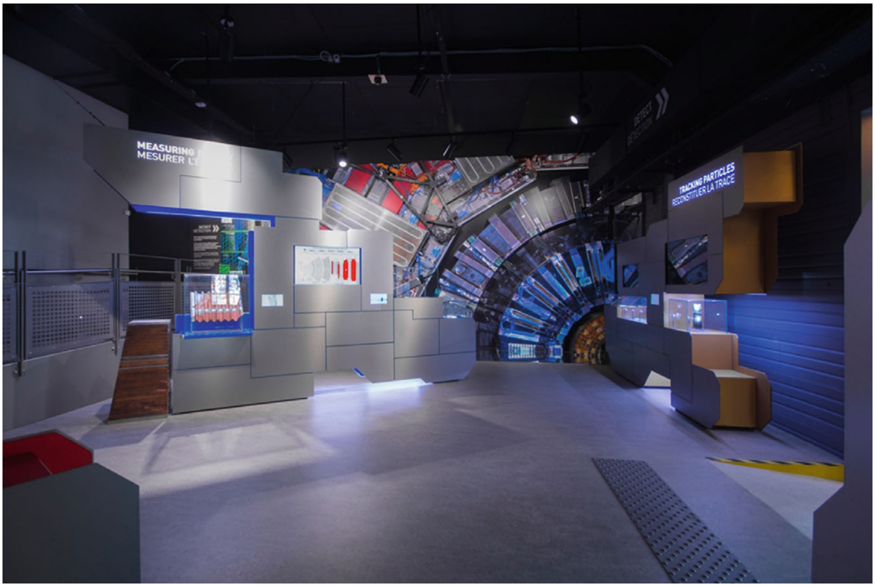

Fig. 1 Inside the Microcosm exhibition. *Credits* CERN

Fig. 2 Inside and outside of the Universe of Particles exhibition. *Credits* CERN

Although 120,000 visits are typically recorded per year, about twice as many requests (300,000) reach the CERN visit service every year. Therefore, it is safe to assume that the number of visitors each year may increase as soon as visit capacities increase, for instance with the newly constructed visitor center. CERN's records only have data on visitors who sign up for a guided tour. However, many visitors also profit from the freely accessible visit facilities without guided tours or are part of dedicated tours to one of the LHC experiments, which are managed by the experiment collaborations and not by CERN's central visit service.

This study aims to answer the question "How much are visitors valuing the knowledge achieved during this visit, and how much they would be willing to pay for it?"

3.1 Prior Efforts

Reference [14] conducted an economic impact assessment of visitors to the CERN site, attributing a conservative discounted value of approximately € 1.1 million to their economic contribution. The study, using data from 2013 as the reference year, covered the observation period from 2004 to 2025. The benefits estimation employed the revealed preference method, anchored in the Marginal Social Value (MSV) of the time spent during visits to the Large Hadron Collider (LHC).

Historical data on visitor numbers from 2004 to 2013 were obtained from the CERN Education, Communication, and Outreach Group, as well as from each of the LHC experiment collaborations (Alice, Atlas, CMS, and LHCb). Projections extending to 2025 were determined by extrapolating the figures with a consistent annual increment, based on trends observed in prior years. It was assumed that there was an 80% overlap between visitors to the LHC experimental facilities and the permanent exhibitions at CERN, namely Microcosm and Universe of Particles located within the Globe of Science and Innovation. Consequently, only 80% of the total visitor count to CERN was attributed to the LHC/LHC program.

To estimate the benefits, the study employed the travel cost method. Visitors were categorized into three source zones, each representing increasing distances from CERN. Average travel costs for each zone were computed using cost benchmarks derived from seven source cities, considering a combination of transportation modes and length of stay. The economic value of the time spent by travelers was drawn from HEATCO guidelines for each CERN member country, as well as some non-member countries.

Our research distinguishes itself from prior studies by relying on empirical data related to visitor expenditures on travel, on-site visits, accommodations, and local spending. The travel cost method was used to provide a more practical estimate of visitor spending within the region, offering deeper insights into the additional amount visitors would be willing to invest during their visit.

3.2 Methodology

The travel cost method of economic evaluation was formulated by [24] and is a demand theory-based preference disclosure method. The purpose of this method is to relate the characteristics of the cultural resource to the concept of "Willingness to Pay" (WTP) for recreational activities. In this way, it postulates that the existing demand for a place and the WTP for traveling to that place are related. Previous economic evaluations of heritage sites by [25–28] have demonstrated the reliability of this method in assessing the economic impact of visitors and their impact on the region in which the heritage site is located.

In the study, the travel cost (TC) was determined by the survey. In this way, it was possible to determine the total expenditure of the visitors and, based on the theory of marginal utility, to measure economically the benefit of the visitors through the "Consumer Surplus" (CS) using the "Individual Travel Cost Method" (ITCM). CS [27] is the result of the difference between what a consumer pays for a good or service and what the consumer would be willing to pay for it and provides a value that can be considered the visitor's net benefit. This value increases the visitor's initial TC, which is considered the net benefit of the visitor's travel experience. In the case of CERN, consumer surplus shows the additional benefit of visitors reaching the organization's facilities.

The first part of the study analyzes the expenses accrued by visitors throughout their journey, including both; during the trip and in the pre-trip phase, referred to as the methodology for calculating travel expenses (TC). Responses were obtained from a questionnaire administered to visitors between June 2018 and May 2019, comparing seasonal dependencies of spending. Results were acquired by analyzing responses from 900 valid form-based inquiry responses. The visitors reported their actual spending on visiting CERN before and during their trip. The questionnaire asked clearly if the motivation for the trip CERN was or if CERN was a visit carried out during the trip without being the primary motivation for the travel. The questionnaire was anonymous and asked only about age group and country of origin. The averages per person in that group were recorded for a questionnaire handed to an entire group.

Then, two types of scenarios were distinguished. The first scenario includes visitors who come to CERN because it is the purpose of the trip and who have registered for a free visit and are included in the category of registered visitors. The second scenario concerns visitors to the region without having CERN as the primary goal and who have not registered for a particular topical type of visit. These latter visitors were included in the category of unregistered visitors.

The total annual visitor counts in scenario 1 is documented and was supplied by the CERN visitor service. In our survey, we acquired a subset of the overall expenditures made by visitors from specific countries. Regrettably, it was not feasible to gather data on all visitors, let alone obtain a sample representing the entire expenditure by country. Consequently, we had to extrapolate the survey results to encompass countries for which information was unavailable. For these countries, the total trip expenditure was assigned based on the nearest country with available survey records. For scenario 2, the total annual number of unregistered visitors is not known. Each survey was analyzed but no extrapolation to other countries was made. Therefore, this study presents a largely underestimated result for this scenario based on the available survey form responses. The averages of the various individual visitor expenditures (e.g., entrance fees, hotels, souvenirs) were calculated from the factual information provided by the visitors.

The final TC computation has been estimated as follows.

First, the average values of each expenditure reported in the survey responses were calculated. For daily food and transportation, the actual prices for the meals and the public transport tickets were considered. Daily transportation costs were reported as zero in many responses because hotels provide free transportation to visitors. Then, the following formula was applied to obtain the travel cost for the visit per survey response, based on the average values for each category:

$$E_{euro} = \left(Days * Food_{daily}\right) + \left(Days * Transport_{daily}\right) + Accommodation + Tickets + Visit_{museum,exhibition,etc.} + Souvenirs \tag{1}$$

where:

- E_{euro} = Estimated total travel cost in euros.
- Days = Total number of days visitors use on their trip.
- $Food_{daily}$ = Daily food and drinks expenditure.
- $Transport_{daily}$ = Daily transportation spending in the region.
- Accommodation = Total accommodation expenditure during the trip.
- Tickets = Total travel expenses; e.g., tickets, gasoline, toll, etc.
- $Visit_{museum, exhibition, etc.}$ = Total expenditure on visiting other cultural or leisure activities.
- Souvenirs = Total spending on souvenirs during the trip.

Visitors declared that they honestly indicate their spending since the analysis will be included in CERN's future planning for visit services and will therefore have an influence on the evolution of the organization. The expenses declared by the visitors in Swiss francs (CHF) were converted to Euros (EUR) using an exchange rate of 1 CHF = 0.87 EUR.

Then, statistical analysis was performed to estimate consumer surplus (CS) by applying the methodology by Torres-Ortega et al. [27]. The individual travel cost method states that the number of times a person visits a place is inversely related to the total expenditure of that visit. Thus, a demand function can be estimated for the place or location visited. In this case, the demand would be the visitors (Vi) and the price of the product would be the cost of the trip (TCi), giving rise to the following expression:

$$V_i = f(TC_i) + \varepsilon_i \tag{2}$$

where:

V_i = Number of visitors.

TC_i = Total cost of the travel to the site per visitor including travel expenses, meals, accommodation, transport in the region, and entrance fees to exhibitions and souvenirs.

ε_i = Error term.

To estimate the parameters of the function, the above equation is transformed into:

$$Log\ V_i = \beta_0 + \beta_{TC}\, TC_i \tag{3}$$

Having estimated the relevant parameters, and assuming that the coefficient of the variable TC is statistically significant, the CS can be determined as follows:

$$CS = -\,1/\beta_{TC} \tag{4}$$

The 95% confidence interval can be calculated as follows:

$$CS_{L,U} = -\,1/(\beta_{TC} \pm 1.96 * (\text{SE}\, \beta_{TC})) \tag{5}$$

4 Study Findings

The results of the study by scenario are reported below.

4.1 Travel Cost of the Registered Visitor Scenario

In this scenario, we assume that individuals who enroll for guided tours at CERN primarily travel to the area for this specific purpose. Consequently, the TC is fully considered. The methodology for determining the economic benefit in the region is applied individually to each visitor's country of origin, using data from the CERN visit service database, which records visitor numbers and their respective countries of origin.

It's important to note that the average TC of visitors is only available for a subset of countries, as the survey covered visitors from only a fraction of nations. To estimate the TC for visitors from the missing countries, we extrapolated the average TC from adjacent countries with available data and multiplied it by the known number of visitors from the respective country. This extrapolation adhered to the parameters employed in the prior study conducted by [14].

We calculated the country-specific TC averages based on the collected responses, considering the variations across different countries. Subsequently, these values were extrapolated to countries where data was unavailable (Table 1).

Table 1 TC by onsite CERN visitors, registered visitor scenario

TC by onsite CERN visitors, registered visitor scenario	
June 1–September 31, 2018	12,657,632.83 €
October 1, 2018–May 31, 2019	33,155,289.94 €
Total	45,812,922.77 €

Table 2 TC by onsite CERN visitors, unregistered visitor scenario

TC by onsite CERN visitors, unregistered visitor scenario	
June 1–September 31, 2018	209,006.97 €
October 1, 2018–May 31, 2019	204,324.81 €
Total	413,331.78 €

These results suggest that, on average, spending is higher in the autumn to spring season owing to the number of visitors being greater in this period, as a large portion of the visitor groups come from high schools and the visits take place during the school year.

4.2 Travel Cost for the Unregistered Visitor Scenario

In this case, the computation of potential benefits closely followed the methodology used in scenario 1. However, a key difference is that the expenditures were underestimated. This underestimation is attributed to the absence of a comprehensive visitor registry, which necessitated reliance on the sample obtained from the survey (Table 2).

The overall estimated Travel Cost (TC) incurred by visitors to CERN for an entire year, amounts to approximately 46.5 million euros. It's essential to note that these findings are exceedingly conservative. This is mainly because the responses gathered in scenario 2 (the unregistered visitor scenario) did not enable us to extrapolate the data to encompass the entire population of visitors within this group. Additionally, the extrapolations executed in scenario 1 (the registered visitor scenario) are also notably underestimated.

4.3 Consumer Surplus Analysis

To acquire useful values for the parameters of the impact estimation function, many possible combinations of the same function were tested. Visitor values were first differentiated by country. This made it very difficult to obtain an optimal static model, so it was decided to group visitors by periods of the year, in the case of the registered visitor's scenario.

The estimated statistical model is:

$$Log\ V_i = \beta_0 + \beta_{TC}\, TC_i \tag{6}$$

The estimation of CS distinguished visitors in the two scenarios described above.

4.3.1 Consumer Surplus for the Registered Visitor Scenario

The survey revealed the TC per visitor for a sample of countries. In this case, the number of visitors per country is known, and by determining the average TC sample of representative countries, it was possible to extrapolate this travel expenditure to all registered visitors per country. Since the sample of registered visitors is sufficiently large, it has been decided to separate it into the two seasons of the year: summer and winter. The results obtained in this scenario are shown in Tables 3 and 4.

The following result has been obtained by applying the equation to determine the Consumer Surplus.

$$\text{Consumer Surplus (CS)} = -1/\beta_{TC} = 0.80\,€$$

The 95% confidence interval can be calculated as follows and has the following results.

$$CS_{L,U} = -1/(\beta_{TC} \pm 1.96 * (\text{SE}\,\beta_{TC})) \quad (7)$$

The confidence interval obtained shows that CS can range from 0.40 to 30 €. The total annual CS for the 21,154 observations, is 16,802.2 €, with a 95% confidence interval from 8514.1 to 633,126 €.

As with the TC of the visit, in this case, a very conservative value was obtained, since only a rough estimate of visitor spending could be made.

The following result has been obtained by applying the equation to determine the Consumer Surplus.

$$\text{Consumer Surplus (CS)} = -1/\beta_{TC} = 0.62\,€$$

Table 3 Consumer surplus coefficients onsite CERN visitors, registered visitor summer scenario

Variable	Coefficient	Standard error
Constant	12.5171**	4.1195
Travel cost (TC)	− 1.2590*	0.6253
Number of observations	21,154	

Significative codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 4 Consumer surplus coefficients onsite CERN visitors, registered visitor winter scenario

Variable	Coefficient	Standard error
Constant	14.7034**	4.7093
Travel cost (TC)	− 1.6100*	0.7213
Number of observations	61,652	

Significative codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5 Consumer surplus coefficients onsite CERN visitors, unregistered visitor scenario

Variable	Coefficient	Standard error
Constant	5.87873***	0.38062
Travel cost (TC)	− 0.10278	0.05817
Number of observations	494	

Significative codes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The 95% confidence interval can be calculated as follows and has the following results.

$$CS_{L,U} = -1/(\beta_{TC} \pm 1.96 * (\text{SE}\,\beta_{TC})) \quad (8)$$

The confidence interval obtained shows that CS ranges between 0.33 and 5.1 €. The total annual CS for the 61,652 visitors, is 38,293.2 €, with a 95% confidence interval from 20,389.3 to 314,147.1 €.

4.3.2 Consumer Surplus for the Unregistered Visitor Scenario

The model analyzed, in this case, yields the results shown in Table 5.

As expected, the impact of the Travel Cost estimate is negative and significant ($p < 0.05$). It can be confirmed that as the cost of travel increases, the number of visitors decreases. Applying the equation to determine the Consumer Surplus, the following result was obtained.

$$\text{Consumer Surplus (CS)} = -1/\beta_{\text{TC}} = 9.73\,€$$

The 95% confidence interval can be calculated as follows and has the following results.

$$CS_{L,U} = -1/(\beta_{TC} \pm 1.96 * (\text{SE}\,\beta_{TC})) \quad (9)$$

The confidence interval obtained indicates that the consumer surplus can range from 4.61 to 9.84 €. The total annual consumer surplus for 494 observations is 4806.4 € with a 95% confidence interval of 2278.7–4862.71 €.

The result of the TC is € 46 million, increased by 59,901.8 € owing to the ex-post analysis of the consumer surplus, which measures the increase in the original visitors' TC because of the experiences they have and the knowledge they acquire during their visit to CERN.

5 Conclusions

Many researchers and institutions have demonstrated the great economic and societal impact of CERN, but it is worthwhile to examine and document the return on taxpayers' contributions to this research infrastructure. The survey conducted in this study has made it possible to estimate the TC and determine the benefit to these visitors of the knowledge acquisition they experience during their visit.

The quantification of the TC of onsite visits was determined using a questionnaire-based approach to reveal the average expenditures that visitors make during their visit. The resulting TC value was about 46 million € for the period from the beginning of June 2018 to the end of May 2019, which is equivalent to 552 € per visitor. From this data, a regression analysis was performed to determine the consumer surplus of these visitors, estimating a monetary value equivalent for the knowledge experience all visitors gain from their visit at a total of 59,901.8 €, on average at least 0.72 € over the cost of the trip.

The value of the consumer surplus has been used to conservatively measure the willingness of visitors to pay for the experience of visiting CERN and learning from the daily research of the staff.

This study has shown to our best knowledge for the first time, a robust estimate of the benefit to visitors of traveling to and experiencing CERN. Although a single in-depth study has been conducted, in the future the small deficiencies in developing the estimate should be corrected concerning the quality of the available visitor data by planning and carrying out long-term systematic monitoring with a continuous visitor survey. The organization has a record of visitors who are registered to visit CERN, whether it is for experiments or the official visit, but not of individual visitors who have not registered and simply come to the organization to enjoy it like a museum. A long-term data set of the spending is also missing. This makes it difficult to draw general and robust conclusions. This situation could be mitigated by introducing a registration and questionnaire system for each visitor to CERN so that a full accounting of all visitors to CERN can be made for statistical analysis purposes.

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