

# Social Cost-Benefit Analysis of Research Infrastructures: New Empirical Evidence from CERN

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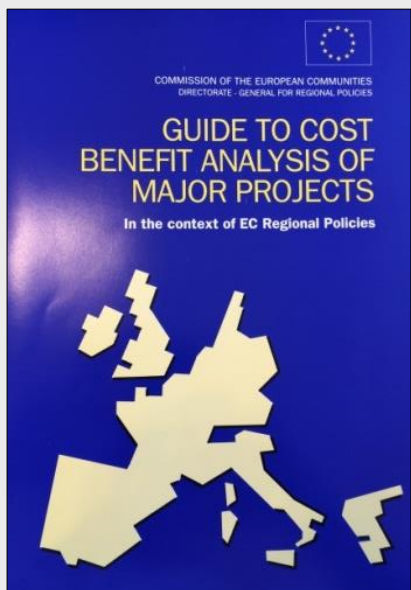


# OUTLINE

Since six years now a team of the University of Milan has developed a social cost-benefit analysis of large scale investments in science: see Bastianin and Florio (2018, 2019) on HL-LHC and on possible CBA of FCC

- The CBA model in a nutshell
- LESSON 1: New findings on technological spillovers through procurement
- LESSON 2: A new approach to measure the value of free and open source software
- LESSON 3: Validation of previous results on human capital
- LESSON 4: New evidence on cultural effects through social media
- LESSON 5: First contingent valuation experiment with French citizens
- Lessons learned and new research avenues

# SOCIAL COST BENEFIT ANALYSIS



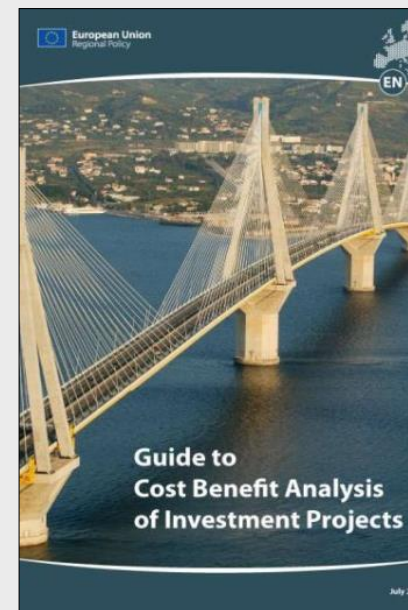
**1994**  
1st edition  
28 pages



**1997**  
2nd edition  
84 pages



**2002**  
3rd edition  
133 pages



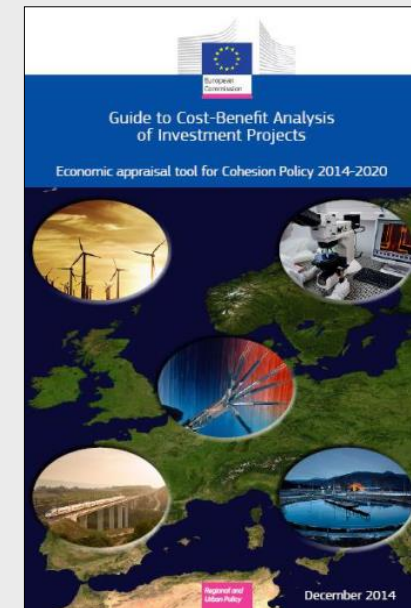
**2008**  
4th edition  
257 pages



**2018 – 2020**



**2017 – 2019**



**2014**  
5th edition  
364 pages

A novelty of the fifth edition of EC CBA Guide:  
Ch. 7 – Research, Development and innovation

# A CBA MODEL FOR RESEARCH INFRASTRUCTURES

The expected economic net present value of the Ris infrastructure ( $NPV_{RI}$ ) over the **time horizon** ( $T$ ) is defined as the difference between expected **benefits** and **costs** valued at shadow prices and discounted at the **social discount rate** ( $r$ )

$$NPV_{RI} = NPV_u + B_n = (PV_{B_u} - PV_{C_u}) + B_n$$

$PV_{B_u}$  = present value of use-benefits

$PV_{C_u}$  = present value of costs

$B_n$  = non use-benefits

$$NPV_{RI} = \left[ \left( \sum_{i=1}^n \sum_{t=1}^J \frac{s_t \cdot P_{it}}{Ref_{it}} + \sum_{i=0}^n \sum_{t=0}^J s_t \cdot CIT_{it} \right) + \left( \sum_{z=1}^Z \sum_{t=\phi}^J s_t \cdot Dw_{zt} \right) + \left( \sum_{j=1}^J \sum_{t=0}^J s_t \cdot II_{jt} \right) + \left( \sum_{ar=1}^n \sum_{t=0}^J s_t \cdot AR_{art} \right) + \left( \sum_{g=1}^G \sum_{t=0}^J s_t \cdot WTP_{gt} \right) \right] + (EXV_0) - \left[ \sum_{t=0}^J s_t \cdot (K_t + L_{ot} + OP_t + EXT_t) \right]$$

DISCOUNT FACTOR

$$S_t = \frac{1}{(1+r)^t}$$

# LESSON 1: LEARNING THROUGH PROCUREMENT (1)

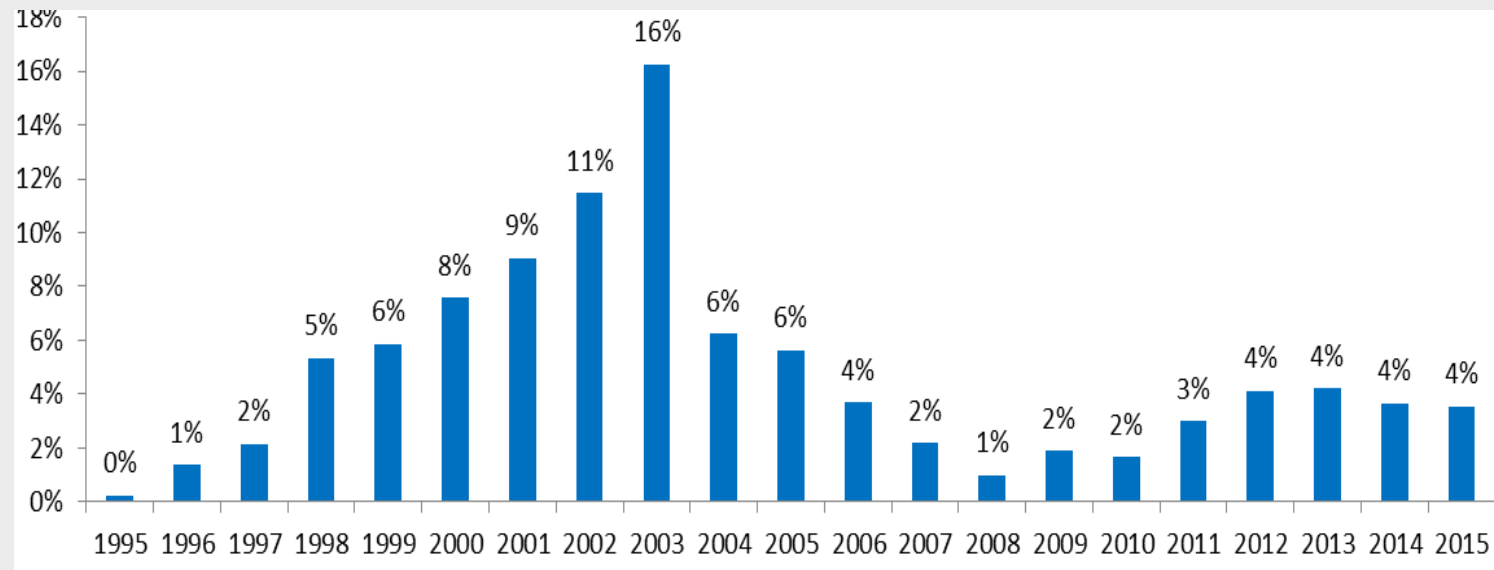
## The procurement activity of CERN\*

4,204 suppliers from 47 countries

33,414 orders

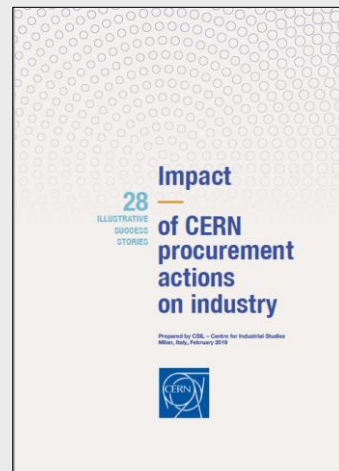
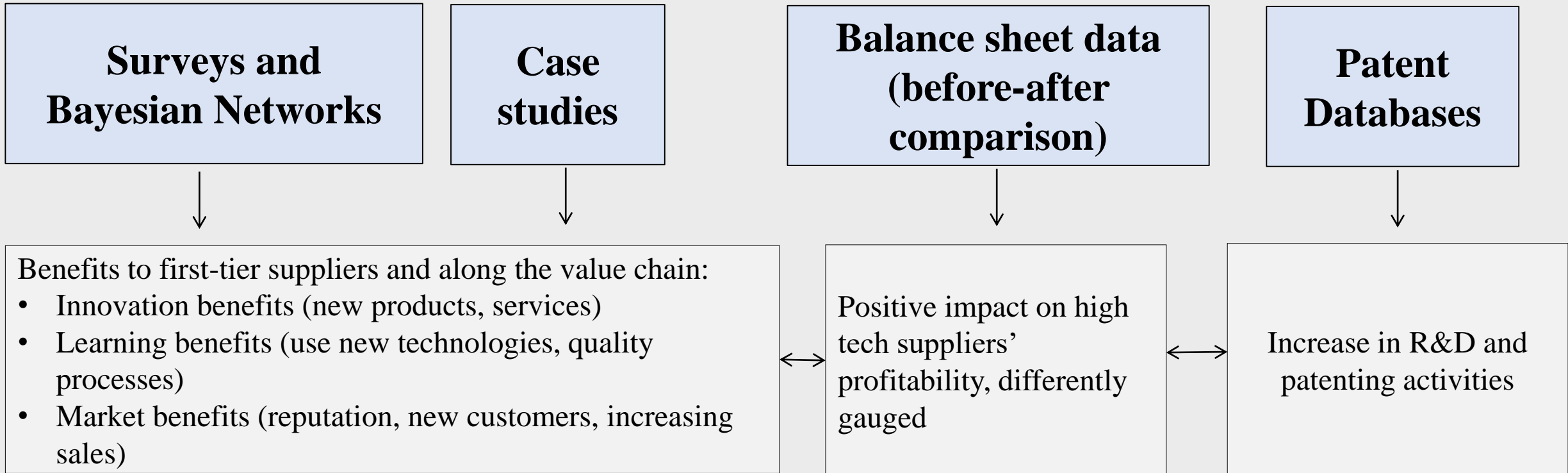
4.3 Billion CHF of expenditure

Volume of the orders by year %



\* Sample of orders > 10,000 CHF

# LESSON 1: LEARNING THROUGH PROCUREMENT (2)



Sirtori, E. C., Florio, M., Catalano, G., Caputo, A. C., Pancotti, C. C., and Giffoni, F. (2019). *Impact of CERN procurement actions on industry: 28 illustrative success stories*. CSIL – Centre for Industrial Studies (Milan), CERN (Geneva). [http://cdsweb.cern.ch/record/2670056/files/CERN-BOOKLET\\_DIGITAL-VPC.pdf](http://cdsweb.cern.ch/record/2670056/files/CERN-BOOKLET_DIGITAL-VPC.pdf)

# LESSON 1: LEARNING THROUGH PROCUREMENT (3)

For the first time we show the impact of procurement on suppliers' performance by a structural model (system of simultaneous equations)

**Findings:** The coefficients obtained from the estimation of the system highlight the direct effect of procurement on R&D investments as well as its mediated impact on company innovation output, productivity and revenues. For non high-tech there is no significant effect

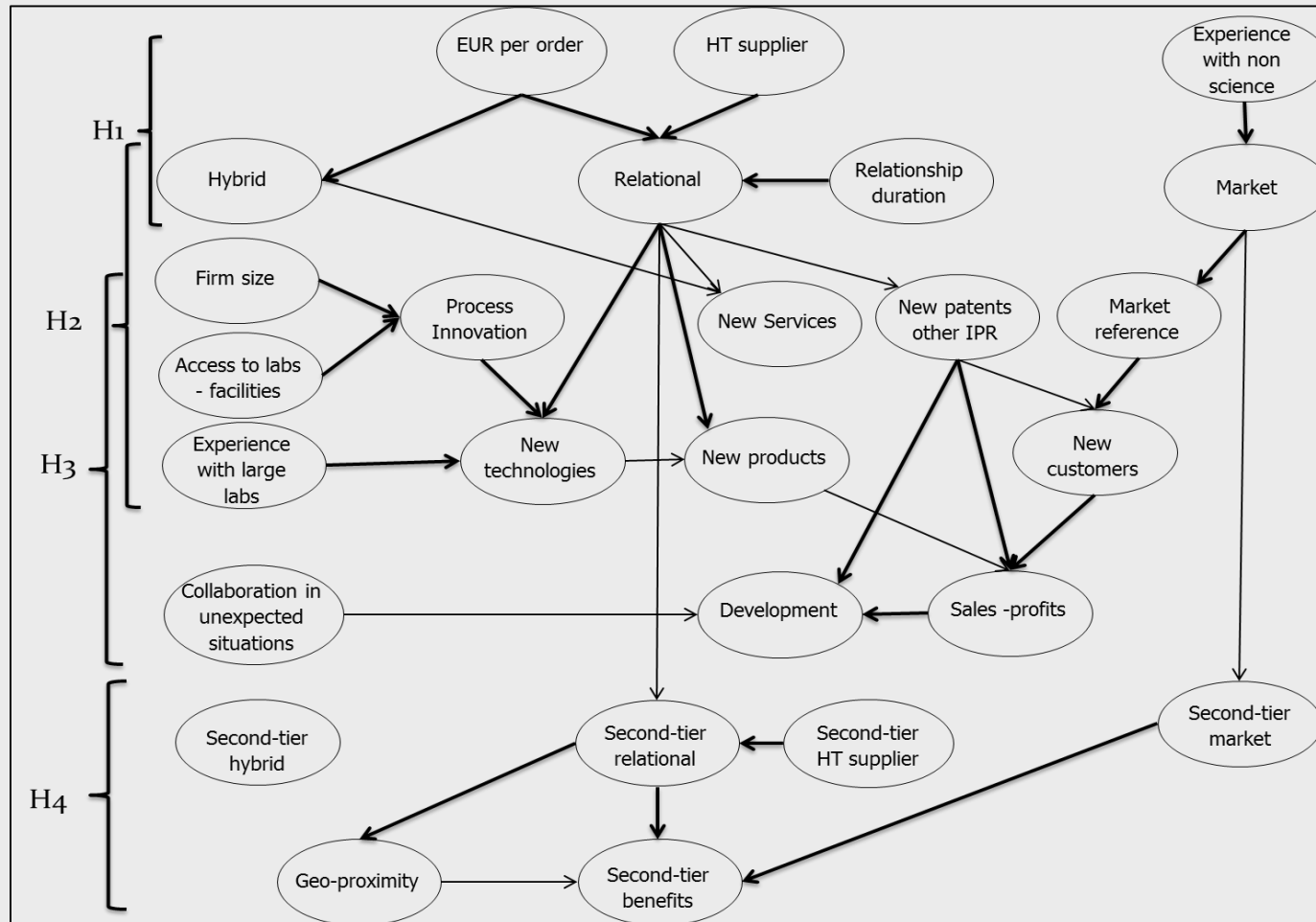


$$\begin{cases} \Delta R\&D_{jt} = \beta_1 CERN_{jt} + \Delta Size'_{jt}\gamma_1 + \theta_1 \Delta GDP_{ct} + \omega_1 \Delta CPI_{ct} + \sigma_s + \eta_t + \rho_c + u_{jt} \\ \Delta Patents_{jt} = \beta_2 R\&D_{jt} + \Delta Size'_{jt}\gamma_2 + \theta_2 \Delta GDP_{ct} + \sigma_s + \eta_t + \rho_c + e_{jt} \\ \Delta Productivity_{jt} = \beta_3 \Delta Patents_{jt} + \Delta Size'_{jt}\gamma_3 + \theta_3 \Delta GDP_{ct} + \omega_3 \Delta CPI_{ct} + \sigma_s + \eta_t + \rho_c + \varepsilon_{jt} \\ \Delta Revenues_{jt} = \beta_4 \Delta Productivity_{jt} + \Delta Size'_{jt}\gamma_4 + \theta_4 \Delta GDP_{ct} + \omega_4 \Delta CPI_{ct} + \sigma_s + \eta_t + \rho_c + \epsilon_{jt} \end{cases}$$



# LESSON 1: LEARNING THROUGH PROCUREMENT (4)

## Bayesian network analysis confirms that learning arises from relational governance



- **Findings:**
  - Innovation benefits
  - Learning benefits
  - Market benefits
- **Key mechanisms:**
  - The way how CERN interacts with its suppliers
  - The type and volume of orders

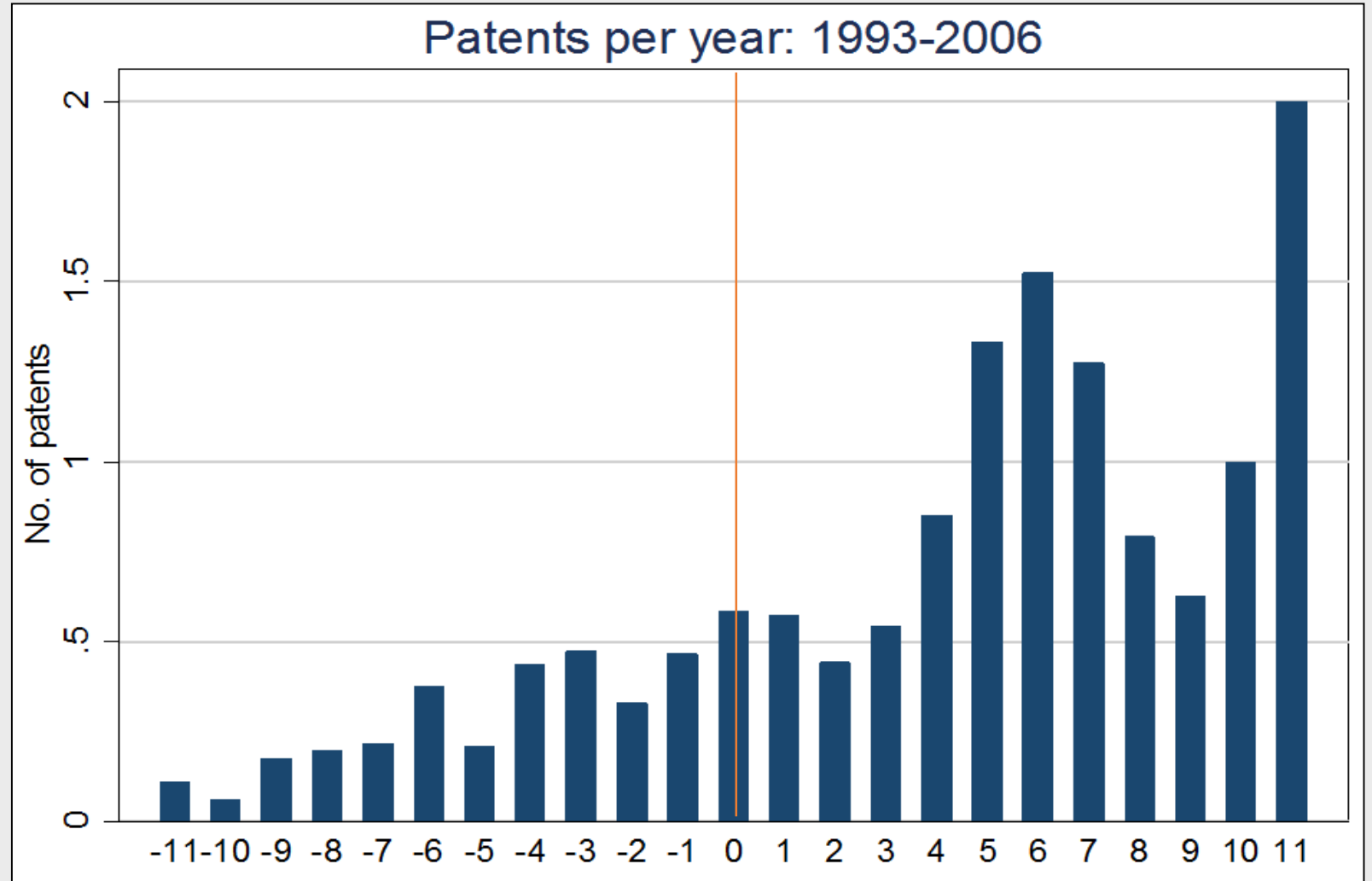




# LESSON 1: LEARNING THROUGH PROCUREMENT (5)

## Impact on suppliers' patenting activity, with a long gestation lag

- CERN effect on innovation, but it takes time to build
- The gestation lag is up to year 5-8 from the first procurement event

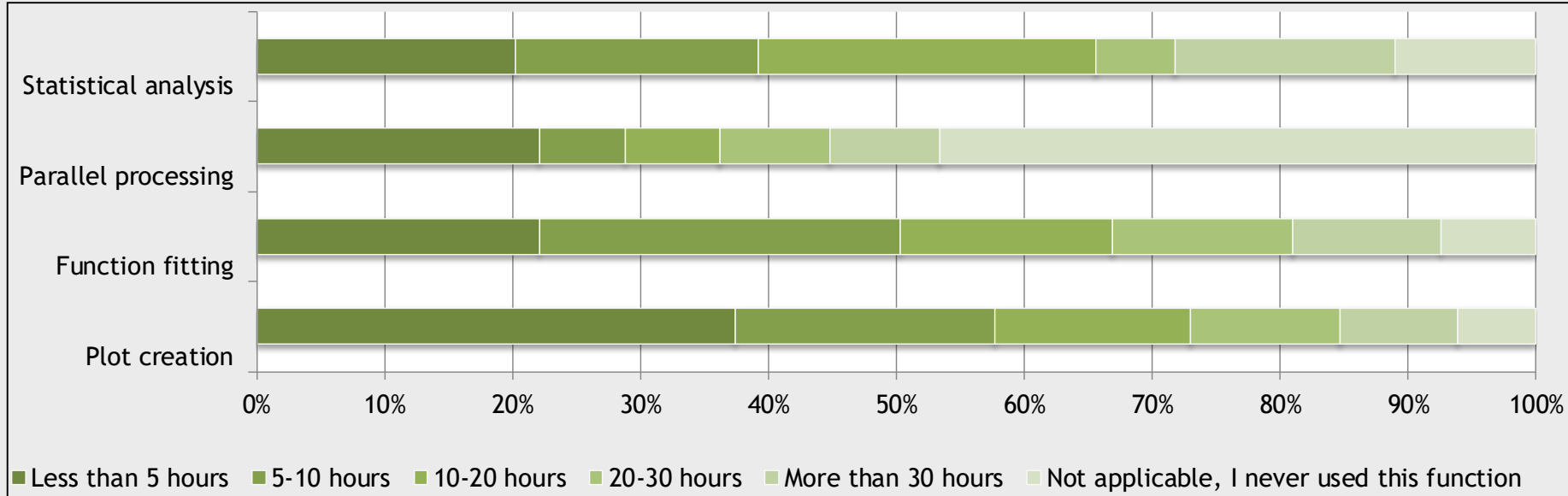


# LESSON 2: THE VALUE OF FREE AND OS SOFTWARE

- A pilot case study on ROOT
- Community of 25-35,000 users (guess)
- ~200 users interviewed (62% CERN MS, 20% USA, 18% Other Countries) → Employees 32%, PhD 26%, students 42%
- Time saved thanks to ROOT compared with alternatives
- Value of time based on average salaries of users

## Findings:

- **Present value of ROOT: 1.7 - 2.1 bn EUR (1994-2025)**
- Value higher than the value estimated by Florio Forte Sirtori, 2016 (714 million EUR) based on price of alternative software
- New estimates is also higher than COCOMO (production cost) = \$30.1 million per year.

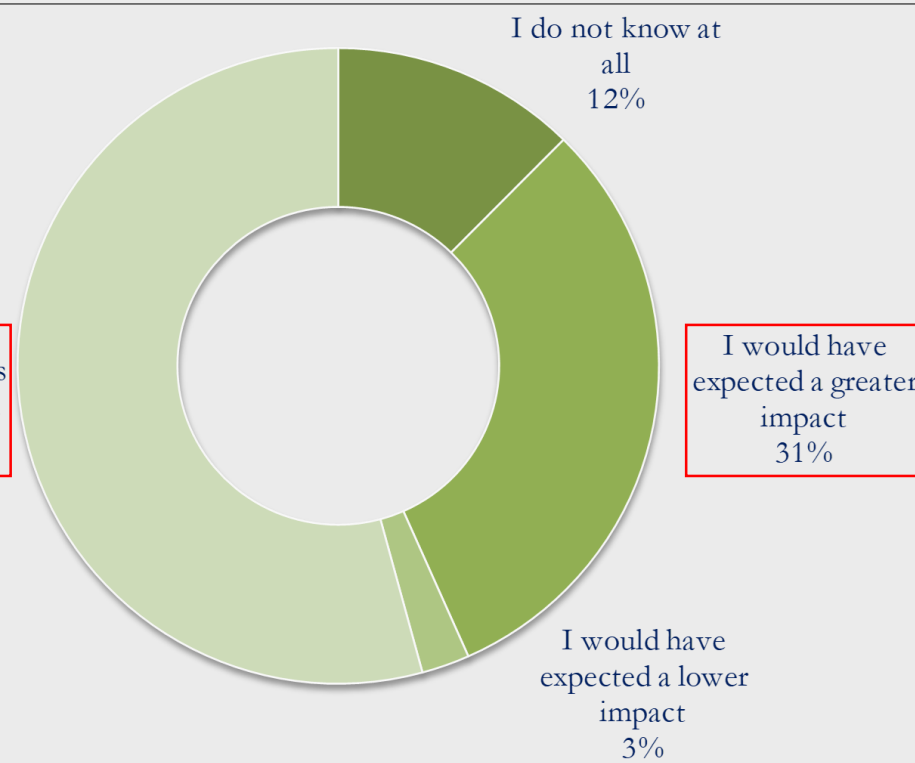


# LESSON 3: CERN AS HUMAN CAPITAL INCUBATOR

- Survey to 332 team leaders (ALICE, ATLAS, CMS, LHCb and others), who know both their students at CERN and not going to CERN
- **85% team leaders agree with their students and post doc about the range of salary premium**

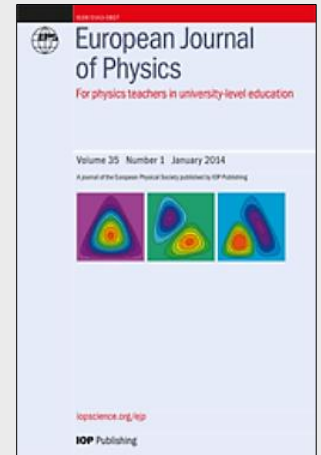
**Question:** “In a recent survey, current and former students at LHC and experiments (some of them now employed outside HEP) put a price tag on their learning experience: a ‘salary premium’ ranging from 5% to 12% compared with what they would have expected for their career without such an experience at CERN”

The range sounds reasonable to me  
54%



I would have expected a greater impact  
31%

I would have expected a lower impact  
3%



Catalano, G., Portaluri, T., Morretta, V., and Florio, M. (2018). *The Value of Human Capital Formation at CERN*. <http://cds.cern.ch/record/2635864/files/CERN-ACC-2018-0025.pdf>

Camporesi, T., Catalano, G., Florio, M., and Giffoni, F. (2017). Experiential learning in high energy physics: a survey of students at the LHC. *European Journal of Physics*, 38(2), 025703

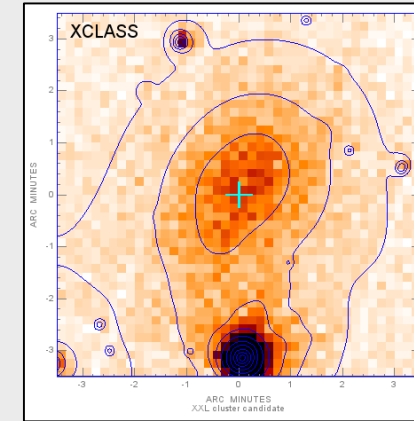
# LESSON 4: THE VALUE OF FUN

## The economics of 'wow' : outreach creates value

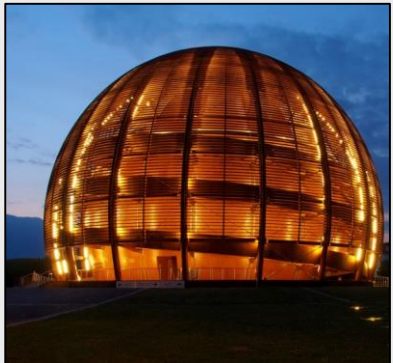


- **The NASA Kennedy Space Center (KSC):**
- More than 1.5 million visitors per year
- February 2018: NASA Facebook had 20,911,149 “likes” and 20,937,006 followers

- **Zooniverse:** online platform displays several projects. Possibility to *millions* of amateur scientists to analyze data in different domains



THE HUNT FOR GALAXY CLUSTERS TALK: EXPLORE THE DEPTHS OF THE UNIVERSE WITH GALAXY CLUSTERS



- **Public cultural value of CERN (1993-2038):**
- 5,1 mln CERN visitors
- 775 mln visitors to the sites
- 1,6 mln visitors to CERN’s exhibitions
- 29,3 mln of social media Users

- **Science Gateway project (2020 – 2022):**
- New scientific education and outreach, public of all ages
- Mission: share knowledge and technology with society, inspire younger generations with the beauty of science
- Science Gateway building will offer a variety of spaces and activities
- Exhibitions



DESIGNED BY RENZO PIANO, FUNDED THROUGH EXTERNAL DONATIONS

Source: LHC related publications. [http://fcc-cdr.web.cern.ch/webkit/press\\_material/Brochure\\_A5\\_SocioEconomic\\_EN.pdf](http://fcc-cdr.web.cern.ch/webkit/press_material/Brochure_A5_SocioEconomic_EN.pdf)

# LESSON 4: THE VALUE OF FUN

## Study of the impacts of cultural and outreach activities carried out at CERN

The annual WTP of YouTube CERN-related visitors was calculated as follows:

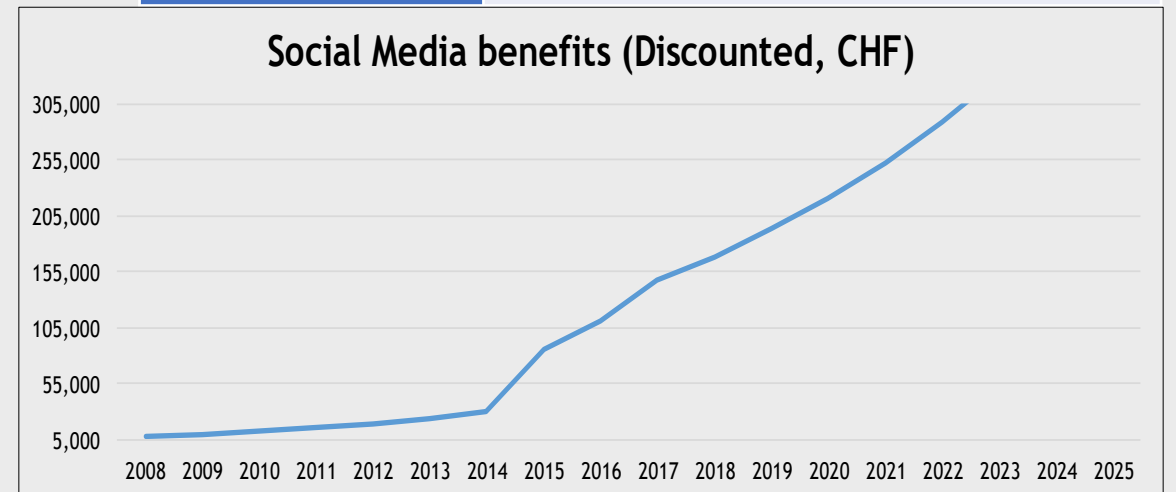
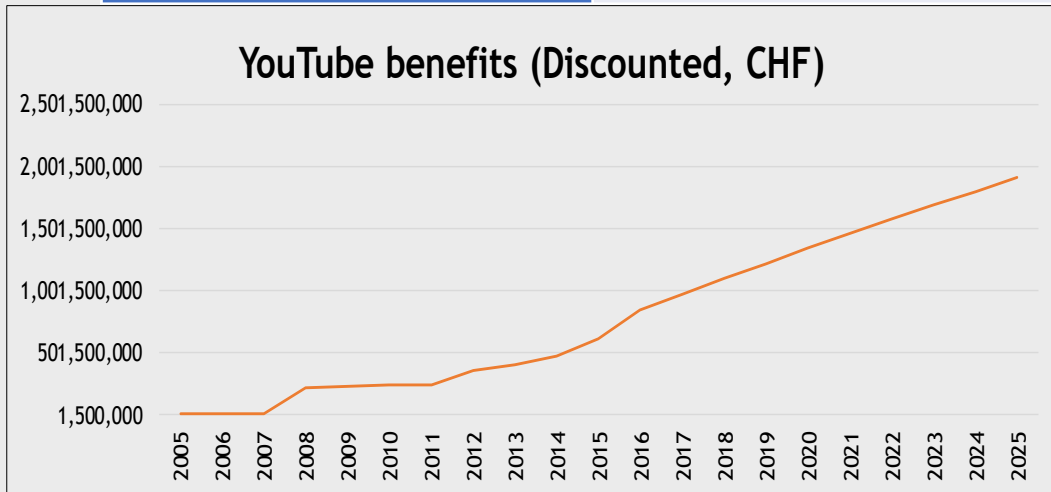
[Number of views (reduced) \* duration of video (in minutes)  
\*social value of time (EUR 0.13 per minutes)]

Cultural channel	Discounted Benefit, CHF Mln
YouTube	1,908
Social Media	2.7
Permanent Exhibitions	3.9
Web Sites	427
Travelling Exhibitions	48
<b>Total Benefit</b>	<b>2,390</b>

The annual WTP of CERN webpages ‘visitors’ was then calculated as follows:

[Number of visits \* average time spent for the visit (in minutes)\*  
social value of time (EUR 0.13 per minutes)]

	TOTAL BENEFIT CHF (DISCOUNTED) Thousand
ALICE	173
ATLAS	3,828
CERN	422,046
CMS	898
LHCb	97
<b>TOTAL BENEFIT</b>	<b>427,043</b>





# LESSON 5: PUBLIC GOOD VALUE, TAX-PAYERS (2)

## Contingent Valuation (CV) – Experiment with French taxpayers

### Ethics

- Respect of the privacy (Code ICC/ESOMAR)
- Anonymity (France Law – n 78-17 Jan 1978)
- Treatment of data
  - ✓ scientific purposes
  - ✓ destruction after 5 years
- Voluntary participation
- No conflict of interests

**Informed consent to be signed before starting the survey approved by the Ethic Committee of the University of Milan**

ENQUÊTE SUR LE SOUTIEN CROÏEN AUX RECHERCHES SCIENTIFIQUES MÈNÉES AU CERN ET AUX INVESTISSEMENTS ASSOCIÉS  
(Bulle FOC: ED416.1790448 | FOC:1704100850 | V1.0 | 10 novembre 2017)

**Consentement éclairé**  
Nous vous prions de bien vouloir lire le présent document avant de participer à l'enquête.


Madame, Monsieur,

Nous vous invitons à participer à une enquête afin de connaître votre opinion sur la valeur des activités de recherche menées au CERN (Organisation européenne pour la recherche nucléaire), organisation internationale dont la convention a été ratifiée en 1954 et modifiée par des amendements en 1971.

L'enquête est réalisée pour le compte du CERN par la société Eumetris Montecore S.r.l. et l'Université de Milan (Italie). Elle a été approuvée par le Comité d'éthique de l'Université de Milan (DATE).

Vous faites partie des personnes sélectionnées par la population française et invitées à s'exprimer sur ce qui est grandement apprécié, et votre opinion est prise en compte pour le renforcement des activités de recherche menées au CERN (contrat en tant qu'étudiant ou membre du personnel associé, relations contractuelles ou sous-traitants) ne vous permet pas de

Pendant cette enquête, nous vous présentons les activités de recherche du CERN au moyen d'une vidéo (environ deux minutes) et d'un document court (environ deux pages). Nous vous demandons ensuite d'exprimer votre opinion sur les activités de recherche menées au CERN et d'indiquer si vous seriez prêt(e) à soutenir de nouveaux investissements pour ce type de recherches.



ENQUÊTE SUR LE SOUTIEN DE LA POPULATION À LA RECHERCHE SCIENTIFIQUE AU CERN

SECTION A : VOS CENTRES D'INTERETS

A.1 Dans quelle mesure êtes-vous intéressé(e) par les sujets suivants ? Répondiez en cochant un ou plusieurs cases correspondantes à votre choix.	Foix de tout	Toujours	Un peu	Aussé	Ne jamais
A.1.1 Sports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.2 Politique et Société	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.3 Voyage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.4 Physique	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.5 Astronomie	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.6 Géologie	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.7 Médecine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.8 Environnement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A.1.9 Architecture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Expository clarity
- Understandable for the public
- Informative and realistic
- Shortness
- Data controls
- Two modalities of data collection based on web users in France\*
  - ✓ CAWI – 88% (877)
  - ✓ CAPI – 12% (123)

\*Eurostat ICT Household survey 2017

### Make respondents aware about CERN

Two-page description of what CERN is and what it does

QU'EST-CE QUE LE CERN ?

Le CERN (Conseil Européen pour la Recherche Nucléaire) est une organisation internationale pour la recherche scientifique en physique fondée en 1954. L'objectif de cette recherche est la compréhension des particules élémentaires. Son site se trouve à Chambéry sur la frontière franco-suisse, près de Genève. Il regroupe les installations d'une des plus grandes organisations de recherche scientifique. Le CERN compte aujourd'hui 22 États membres et 170 États membres associés.

Membre États du CERN



Au CERN, les physiciens explorent les structures fondamentales de l'univers avec de puissantes expériences scientifiques et développent les technologies d'avant-garde. Ces particules sont en fait les briques de base de la matière et de l'énergie. Les particules élémentaires sont étudiées pour comprendre comment elles interagissent et comment elles ont été créées au début de l'univers.

Le CERN est un lieu où se trouvent les installations les plus avancées de physique nucléaire et de physique des particules au monde. Il se trouve dans un lieu unique, à la frontière franco-suisse, près de Genève. Le CERN est une organisation internationale de recherche scientifique qui a pour but de comprendre comment les particules interagissent et comment elles ont été créées au début de l'univers.

Plus de 12 000 scientifiques, ingénieurs, techniciens, étudiants et prestataires de services de nationalités différentes collaborent sur le site du CERN. Ils y font de la recherche en physique fondamentale et en physique appliquée. Ils y font de la recherche en physique appliquée. Ils y font de la recherche en physique appliquée. Ils y font de la recherche en physique appliquée.

Plusieurs technologies issues du CERN ont trouvé des applications dans d'autres domaines. Le World Wide Web, qui fait partie du CERN en 1990, est un exemple. Le traitement du cancer avec les accélérateurs de particules en est un autre. Enfin, un grand nombre de logiciels développés au CERN ont contribué à rendre plus efficace les bases de données numériques, à améliorer le contrôle des lignes aériennes, à améliorer le contrôle qualité, à améliorer la sécurité de plus en plus grande.

Le CERN participe aussi à des projets scientifiques internationaux, au-delà de la physique des particules. Il est impliqué dans le projet ITER pour apporter de l'énergie nucléaire via l'énergie contrôlée. C'est également le cas du projet MEDIC@MIRIS pour développer des médicaments innovants pour l'imagerie médicale et du projet SCARLETT qui vise à concevoir un accélérateur de particules pour la formation des technologies, la science des matériaux, la biologie, l'archéologie et la chimie.

Le CERN a fait de son programme éducatif une priorité. Plus de 100 000 étudiants et stagiaires du monde entier ont été accueillis par le CERN ces dernières années. Le CERN organise de nombreuses sessions de formation et de conférences et de plus en plus de personnes ont été impliquées dans le monde entier.

2 minute video showing what particle physics research at CERN consists of





# LESSON 5: PUBLIC GOOD VALUE, TAX-PAYERS (3)

## Survey to France tax-payers

### PREAMBLE

Particle accelerator research, including the Large Hadron Collider (LHC) at CERN, has established a theoretical representation of the Universe. However, the research highlights phenomena that can not be explained by this theory.

CERN Member States, including France, are financing this research. Here are two possible scenarios for the future of this research

### Scenario A

CERN Member States decide to invest in a new particle accelerator in the next decade. It will make discoveries on phenomena that cannot be explained today. This new accelerator will be operated for at least twenty-five years

### Scenario B

CERN Member States decide not to invest in a new particle accelerator. The research activity with the existing accelerator, the LHC, will gradually decrease over the next twenty years. The possibility of finding answers on unexplained phenomena will remain limited

### WTP QUESTION

### REFERENDUM-LIKE QUESTION (NOAA Guidelines)

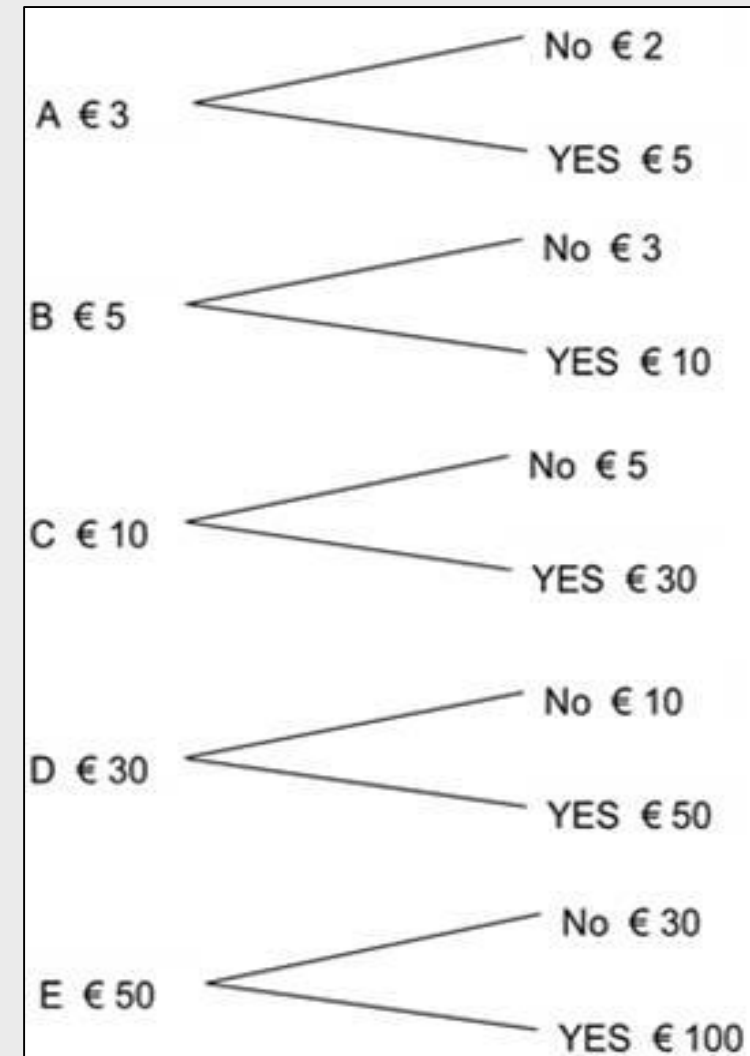
Would you agree to pay the amount of **EUR X** per year as a **taxpayer** for the construction of a new particle accelerator at CERN as described in scenario A?

# LESSON 5: PUBLIC GOOD VALUE, TAX-PAYERS (4)

## How we quantified the WTP – Bidding Scheme

- 5 versions (A,B,C,D,E) of the questionnaire, one for each bid, randomly distributed
- 5 sub-samples, 201 respondents per sub-sample each representative of the French population of voters
- WTP questions with follow-up
- Question on maximum WTP

**E.g. (C) Would you agree to pay the amount of **EUR 10** per year as a **taxpayer** for the construction of a new particle accelerator at CERN as described in scenario A?**



# LESSON 5: PUBLIC GOOD VALUE, TAX-PAYERS (5)

## The bounded conditional average WTP

### Findings:

Unconditional average maximum WTP: **13.5 €**

Bounded conditional average WTP: **4€**

>

Contribution that french citizens actually paid to CERN in the form of taxation in 2017: **2.7 €**

The Double-Bounded Dichotomous Choice Model:

Mean WTP = **f** (income, male, age, education, occupational status, family size, region of residence, awareness of CERN, scientific interest, cultural values)

$$\ln L(\theta) = \sum_{i=1}^N \{ I_i^{YY} \ln[1 - G(t_i^u; \theta)] + I_i^{YN} \ln[G(t_i^u; \theta) - G(t_i^0; \theta)] + I_i^{NY} \ln[G(t_i^0; \theta) - G(t_i^l; \theta)] + I_i^{NN} \ln G(t_i^l; \theta) \}$$

$I_i^{YY} = \mathbf{I}$  (ith respondent' path is "yes-yes")

$I_i^{YN} = \mathbf{I}$  (ith respondent' path is "yes-no")

$I_i^{NY} = \mathbf{I}$  (ith respondent' path is "no-yes")

$I_i^{NN} = \mathbf{I}$  (ith respondent' path is "no-no")

$\mathbf{I}(\cdot)$  takes on the value of one if its argument is true and zero otherwise.

and

$t_i^0$  is the initial bid

$t_i^u$  is the upper bid

$t_i^l$  is the lower bid

$G(t_i; \theta) \equiv \Phi(t_i; \theta)$

$\theta = (\beta, \sigma)$

$$\text{Mean (WTP)} = \tilde{x}' \hat{\beta}$$

$\tilde{x}$  denotes some values of the covariates (e.g. the average value, the value for each individual or groups of individuals), and  $\hat{\beta}$  is the corresponding vector of coefficients to be estimated.

## LESSONS LEARNED

Strong evidence that social CBA is feasible for fundamental science even when the future utility of its discoveries is unknown

1. Technological learning through procurement: strongly confirmed
2. Value of free/OS software: pilot case study based on users' time saved
3. Human capital: Results on salary premium confirmed
4. Cultural effects: new exploratory results from social media
5. Public good value: successful contingent valuation experiment

## FURTHER RESEARCH

- Downstream economic effects of innovation (e.g. vacuum, cryogenics, magnets)
- Software and IT: more data needed on users and benefits
- Human capital: control groups, long term effects
- Cultural effects: analytics needed on CERN impact on the web
- Public good value: replication in Switzerland ongoing. Possibly in other CERN MS

# Thank you!

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[www.massimoflorio.com](http://www.massimoflorio.com)

Stay tuned, new book coming soon:

Florio, M. *Investing in Science.*

*Social Cost-Benefit Analysis of Research Infrastructures,*

The MIT Press, October 2019

<https://mitpress.mit.edu/books/investing-science>

