The socio-economic impact of large-scale research infrastructures: LHC and CNAO

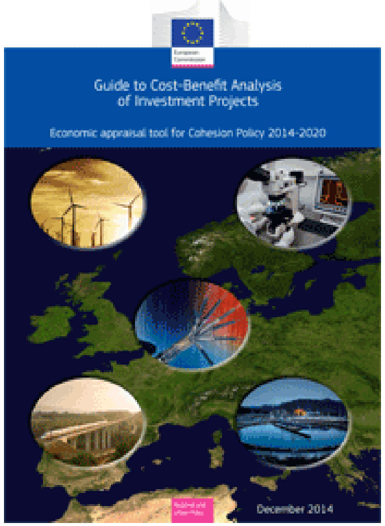
Massimo Florio

Department of Economics, Management and Quantitative Methods
University of Milan

ALBA
Barcelona, 7th October 2016

WHY A CBA MODEL FOR RDI: Motivation and Principles

- **Increasing need for accountability:** RDI at the core of policy agenda, essential component of scientific and technological progress.
- **Peer review process** is designed to assess the scientific case but it is not tailored to evaluate the socio-economic impact of a project.
- **Different evaluation approaches** are related to managerial criteria, financial sustainability, policy priorities and others: these are different from a theory based forecast of socio-economic impacts.
- A **CBA model for RDI** should be firmly based on the theory of **applied welfare economics and empirically implementable**: it must be quantitative.
- What is **unmeasurable** should be left aside, **expressed qualitatively** and is not part of the CBA.



CBA FOR RESEARCH INFRASTRUCTURES

Some information on CBA international practice are drawn from the results of a survey conducted on ***selected OECD countries*** addressing the actual use, practice and role of CBA in ex-ante project appraisal.

OECD, Government at glance

July 2015

http://www.oecd.org/gov/govataglance.htm

Rail *(e.g. Austria, Denmark, Canada, Sweden, Netherlands).*

Urban transport *(e.g. New Zealand, Austria, Denmark, Canada, Sweden, Netherlands)*

Airports, ports and waterways *(e.g. Austria, Canada, Sweden, Netherlands, UK)*

Education *(e.g. Canada, UK)*

Culture and leisure *(e.g. New Zealand, Canada, UK)*

Water supply and wastewater *(e.g. Canada, Netherlands)*

Solid waste management *(e.g. Canada, UK)*

Other environmental projects: risk prevention and mitigation, natural asset conservation, etc. (e.g. *Canada, Sweden, UK)*

ICT: telecommunications, broadband, ICT applications to businesses and citizens *(e.g. Canada, UK)*

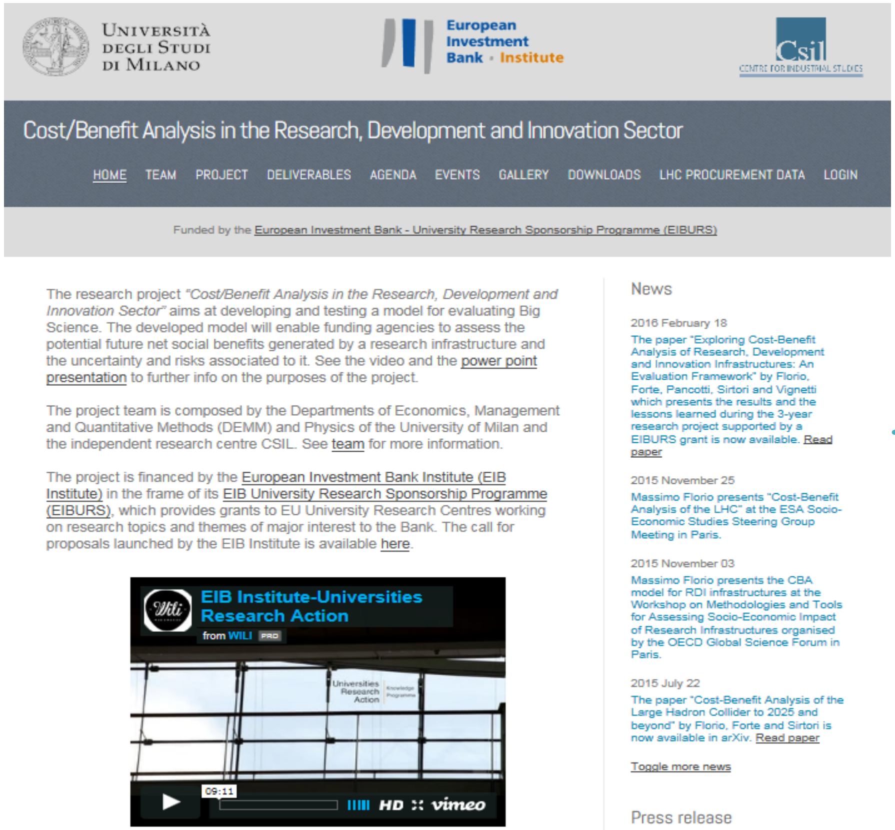
Health *(e.g. Canada, Sweden)*

Energy: production, transmission and distribution (e.g. Denmark, Canada, Sweden)

Scientific research (e.g. Canada, UK)

Technological development and innovation: science parks, technological parks, incubators, etc. *(e.g. Canada, UK)*

Background



EIBURS
EIB University Research Sponsorship Programme
2012-2015

http://www.eiburs.unimi.it/

- Developing a **CBA theoretical model for evaluating research infrastructure projects (RI).**
- Enabling funding agencies to **assess the potential future net social benefits** generated by a RI.
- **Testing the CBA model** on two particle accelerators: LHC and CNAO (National Hadrontherapy Centre for Cancer Treatment).

The CBA model (1)

- The expected economic net present value of the RDI infrastructure $[\mathbb{E}(ENPV_{RDI})]$ 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).***
- The model breaks down ***intertemporal benefits*** into two broad classes – use and non-use benefits – and compares these benefits with costs.
- The expectation operator implies that ***all critical variables are considered as stochastic***.
- All the ***benefits should be related to the main economic agents***: **firms, consumers, employees, taxpayers**.

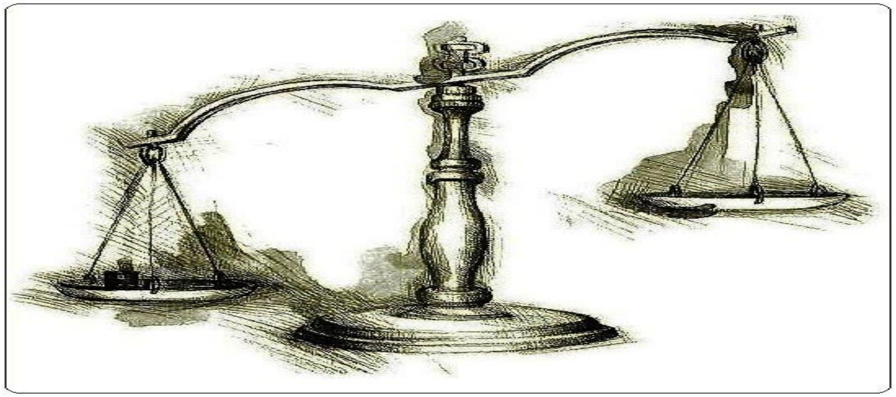
The CBA model (2)

$$\mathbb{E}(ENPV_{RDI}) = \mathbb{E}(EPV_{Bu}) + \mathbb{E}(EPV_{Bn}) - \mathbb{E}(EPV_{Cu})$$

B_u = Use benefits

C_u = Costs

B_n = Non Use benefits



Costs

$\mathbb{E}(\boldsymbol{EPV}_{\boldsymbol{C_u}})$

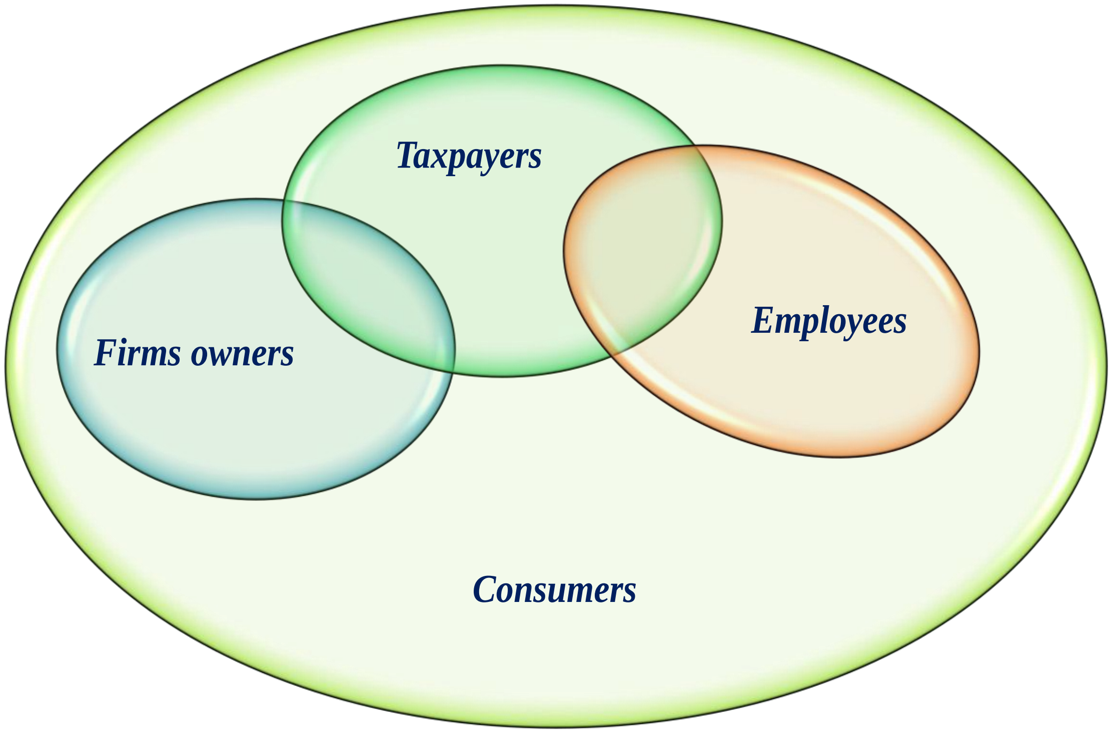
The present value of COSTS is the sum of the:

- **economic value of capital** (K)
- **labour cost of scientists** (L_s)
- other **administrative and technical staff** (L_o)
- other **operating costs** (O)
- **negative externalities** if any (ε).

$$\mathbb{E}(EPV_{C_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (k_t + l_{st} + l_{ot} + O_t + \varepsilon_t)$$

Benefits (1)

Customary partition of economic agents in the applied welfare economics literature:



- **Firms:** profit maximization (producer surplus).
- **Consumers:** maximizing their utility (consumer surplus).
- **Employees:** maximizing their income for a given amount of efforts.
- **Tax-payers:** adjusting their decisions as a consequence of the existing fiscal constraints to minimize the burden of taxation.

Some evidence from literature:

- **Drèze, J. and Stern N. (1990)**. *Policy reform, shadow prices and market prices*, Journal of Public Economics.
- **Johansson, P-O and Kriström, B. (2015**). *Cost-Benefit Analysis for Project Appraisal*, Cambridge: Cambridge University Press.

Benefits (2)

The present value of
BENEFITS
is the sum of the:

- **Firms** (T)
- **Employees** (H)
- **Users** ***(A + S + C)***
- **Taxpayers** $(\boldsymbol{QOV} + \boldsymbol{EXV})$

Firms, Employees, Users: **Use Benefits** $\boldsymbol{B_u}$

Taxpayers: **Non Use Benefits** $\boldsymbol{B_n}$

$$\mathbb{E}(EPV_{B_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (T_t + H_t + A_t + S_t + C_t)$$

$$\mathbb{E}(EPV_{B_n}) = (\text{QOV} + \text{EXV})$$

The CBA model: **Costs and Benefits**

$\mathbb{E}(ENPV_{C_u})$

The present value of COSTS is the sum of the:

- **economic value of capital** (K)
- **labour cost of scientists** (L_s)
- other **administrative and technical staff** (L_o)
- other **operating costs** (O)
- **negative externalities** if any (ε).

$$\mathbb{E}(ENPV_{C_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (k_t + l_{st} + l_{ot} + O_t + \varepsilon_t)$$

The present value of BENEFITS
is the sum of the:

- **Firms** (T)
- **Employees** (H)
- **Users** $(A + S + C)$
- **Taxpayers** $(QOV + EXV)$

Use Benefits B_u (Firms, Employees, Users)

Non Use Benefits B_n (Taxpayers)

$$\mathbb{E}(ENPV_{B_u}) = \sum_{t=0}^{\mathcal{T}} s_t \cdot (T_t + H_t + A_t + S_t + C_t)$$

$$\mathbb{E}(ENPV_{B_n}) = (\mathrm{QOV} + \mathrm{EXV})$$

The CBA model: **Benefits**

Use Benefits B_u

FIRMS

Technological externalities (T_t)

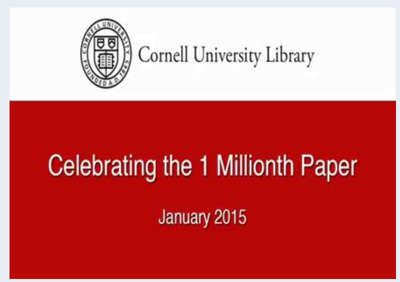
EMPLOYEES: early career researchers

Human Capital Formation (H_t)

CONSUMERS

Social benefits to consumers of services (A_t)

SCIENTISTS



Knowledge output (S_t)

VISITORS

Cultural effects (C_t)

Non Use Benefits B_n

?

Quasi option value (QOV)

TAXPAYERS

Existence value (EXV)

CONSUMERS

Benefits on firms: Technological spillovers

The present value of technological spillovers ($\mathbf{T_t}$) is given by:

- the **discounted incremental social profits $\mathbf{\Pi_{jt}}$** generated by **companies (j)** of the RI's supply chain which have benefitted from a learning effect;
- and **other externalities**.

$$T = \sum_{j=1}^{J} \sum_{t=0}^{\mathcal{T}} s_t \cdot \Pi_{jt}$$

Benefits on employees: Human capital formation

Human capital formation benefits (H **)** are valued as **increased earnings** ($\mathbf{I}$) gained by RI's students and **former employees** ($\mathbf{z}$), since the **moment** ($\boldsymbol{\varphi}$) they leave the project, against **counterfactual scenario**.

$$H = \sum_{z=1}^{z} \sum_{t=\varphi}^{\mathcal{T}} s_t \cdot I_{zt}$$

Benefits on users: knowledge output

The social value of knowledge output is measured by:

- the **sum of the present value of papers signed** by RDI's scientists (P_{0t}) and the **value of subsequent flows of papers produced** by other scientists that use or elaborate of the RDI's scientists' results
- **divided by the number of references** they contain ($\frac{P_{it}}{k_{it}}$, with $i = 1, \dots n$), and the **value of citations each paper receives**, as a proxy of the social recognition that the scientific community acknowledges to the paper (Q_{it} with $i = 0, \dots n$)

$$S = \sum_{t=0}^{\mathcal{T}} s_t \cdot P_{0t} + \sum_{i=1}^{I} \sum_{t=1}^{\mathcal{T}} \frac{s_t \cdot P_{it}}{k_{it}} + \sum_{i=0}^{I} \sum_{t=1}^{\mathcal{T}} s_t \cdot Q_{it}$$

Benefits on users: cultural effects

Outreach activities carried out by RI produce **cultural effects** on the general public (g), which can be valued by estimating the ***willingness to pay of the general public*** for such activities.

$$C = \sum_{g=1}^{G} \sum_{t=1}^{T} s_t \cdot W_{gt}$$

Social benefits to consumers of services

Provision of Services

Some RDI infrastructures provide services to external users. They may pay a fee for accessing and using the infrastructure's equipment and/or specific services offered.

Social benefits of RDI services for target groups of consumers

Some RDI infrastructures are expected to use new knowledge to deliver innovative services and products addressing specific societal needs. Benefits arise to users who are better off by the delivery of the innovative service or product.

Benefits on taxpayers: Quasi Option + Existence value

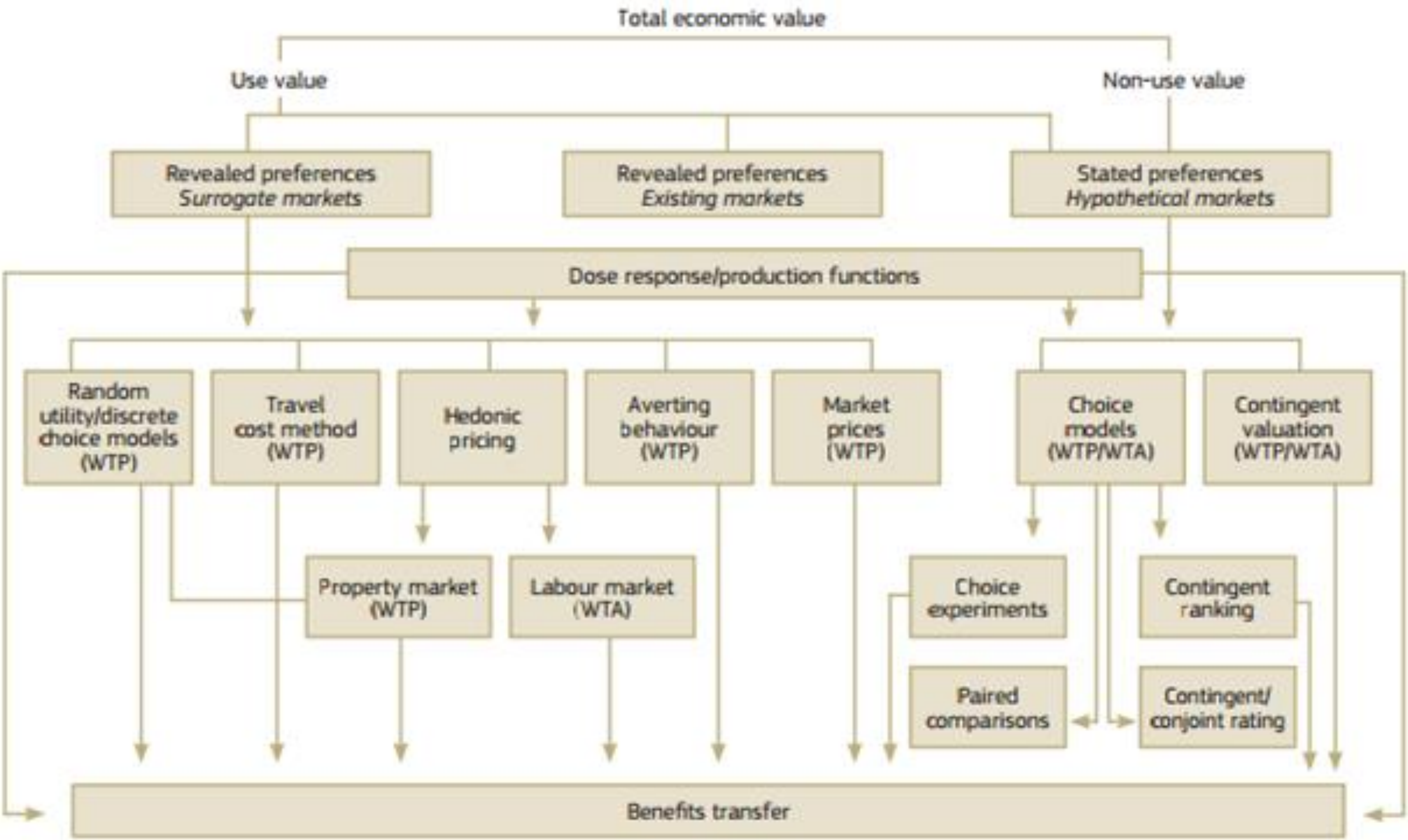
B_n captures two types of benefits related to the social value of discovery: the **quasi-option value** (QOV) and the **existence value** (EXV):

where

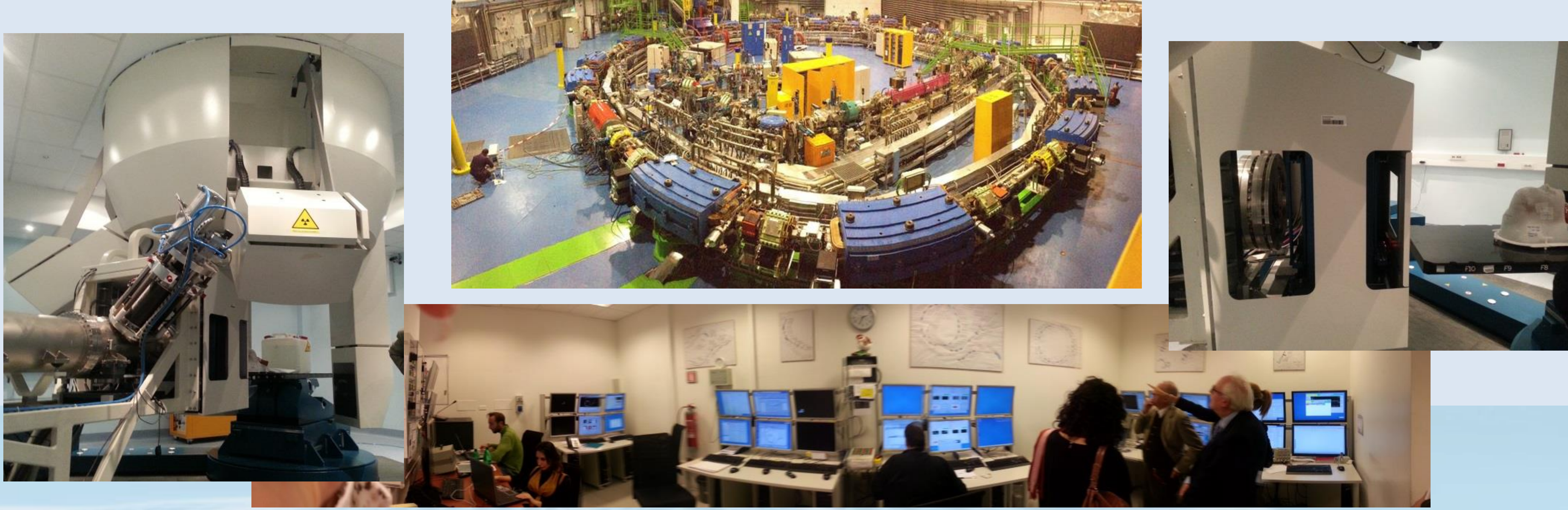
- ***QOV*** is intrinsically ***uncertain*** and therefore ***not measurable***, simply assumed to be ***non-negative*** and then ***skipped***;
- ***EXV***, on the other hand, can be proxied by ***stated or revealed willingness*** to pay for scientific research, and/or through ***benefit transfer***, borrowing ideas from CBA of the environment.

$$B_n = QOV + \mathrm{EXV}$$

Total economic value



Pearce, D.W, Atkinson, G. and Mourato, S. (2006). *Cost-Benefit Analysis and the Environment*. *Recent developments*, Paris: OECD Publishing.

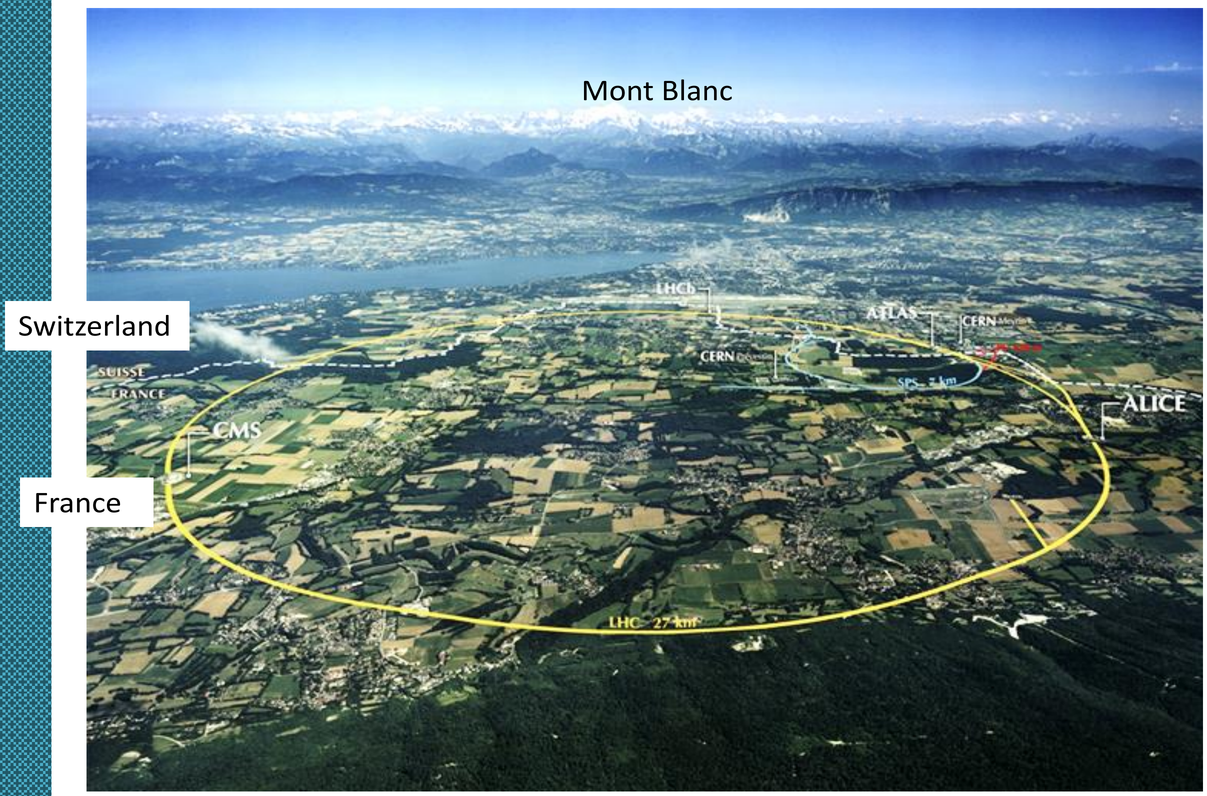


APPLICATION OF THE CBA MODEL

LHC
CASE STUDY

The Large Hadron Collider (LHC)

- It was built (1993-2008) by CERN.
- It is located in a 27 km-long underground tunnel near Geneva.
- In operation since 2009, it has discovered the **Higgs Boson** in 2013.

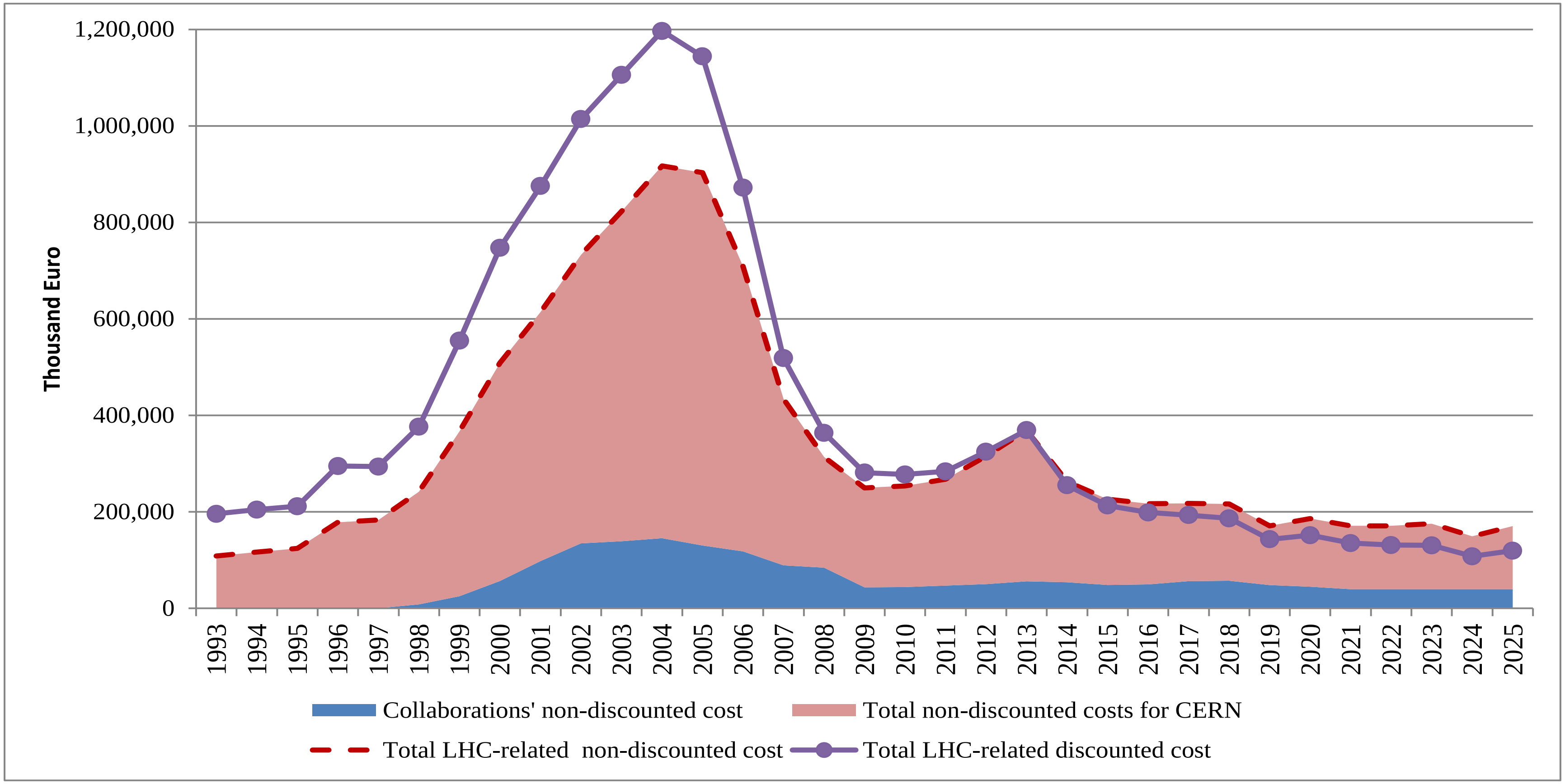


KEY PARAMETERS FOR THE CBA

TIME HORIZON	33 years: 1993 - 2025
UNIT OF ANALYSIS	the LHC and four detectors (collaborations)
SOCIAL DISCOUNT RATE	3% in real terms (adopted by the EC CBA Guide, 2014)
SHADOW PRICES	Proxied by marginal WTP or marginal costs
COUNTERFACTUAL	Business as usual scenario
QUASI-OPTION VALUE	assumed 0
NEGATIVE EXTERNALITIES	assumed 0

LHC: Costs

Total discounted and non-discounted LHC costs covered by CERN and collaborations, including in-kind, by year (1993-2025; thousand euro)



LEGEND OF CERN ACTIVITY CODES

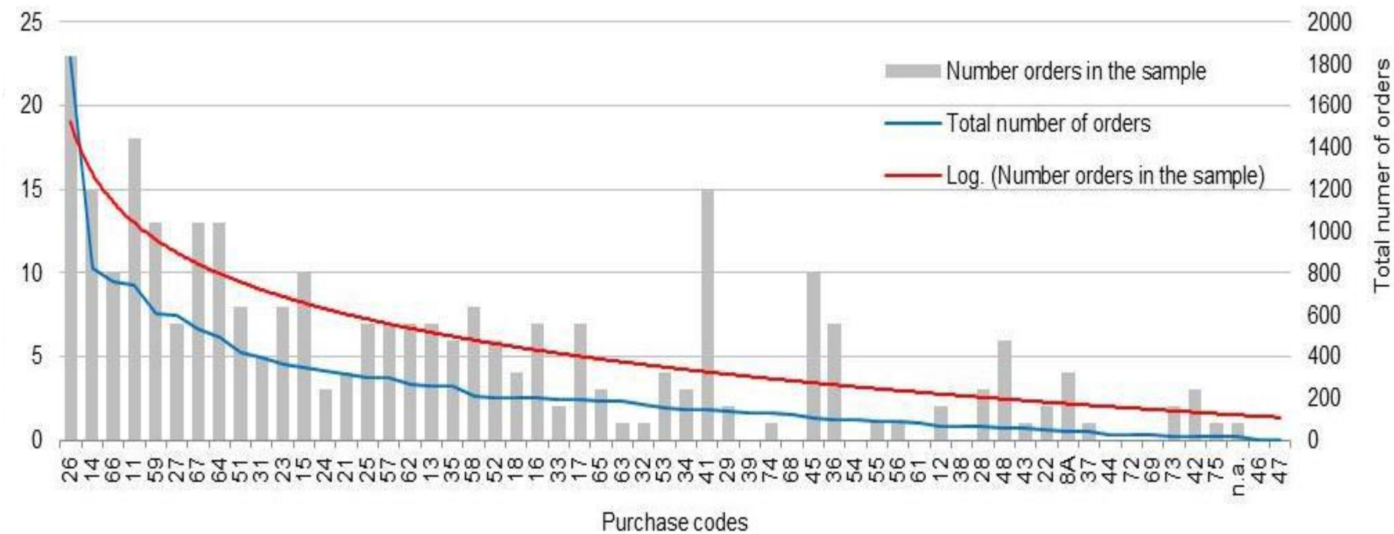
11 building work
12 roadworks
13 installation and supply of pipes
14 electrical installation work
15 heating and air-conditioning equipment (supply and installation)
16 hoisting gear
17 water supply and treatment
18 civil engineering and buildings
21 switch gear and switchboards
22 power transformers
23 power cables and conductors
24 control and communication cables
25 power supplies and converters
26 magnets
27 measurement and regulation
28 electrical engineering
29 electrical engineering components
31 active electronic components
32 passive electronic components
33 electronic measuring instruments
34 power supplies - transformers
35 functional modules & crates
36 rf and microwave components and equipment
37 circuit boards
38 electronics
39 electronic assembly and wiring work
41 computers and work-stations
42 storage systems
43 data-processing peripherals
44 interfaces (see also 35 series)
45 software
46 consumables items for data-processing
47 storage furniture (data-processing)
48 data communication
51 raw materials (supplies)
52 machine tools, workshop and quality control equipment
53 casting and moulding (manufacturing techniques)
54 forging (manufacturing techniques)
55 boiler metal work (manufacturing techniques)
56 sheet metal work (manufacturing techniques)
57 general machining work
58 precision machining work
59 specialised techniques
61 vacuum pumps
62 refrigeration equipment
63 gas-handling equipment
64 storage and transport of cryogens

65 measurement equipment (vacuum and low-temperature technology)
66 low-temperature materials
67 vacuum components & chambers
68 low-temperature components
69 vacuum and low-temperature technology
71 films and emulsions
72 scintillation counter components
73 wire chamber elements
74 special detector components
75 calorimeter elements
8a radiation protection
n.a. not available

LHC: Technological Spillovers (1)

Benefits to suppliers

Sample of 300 orders by purchase code compared with all LHC orders



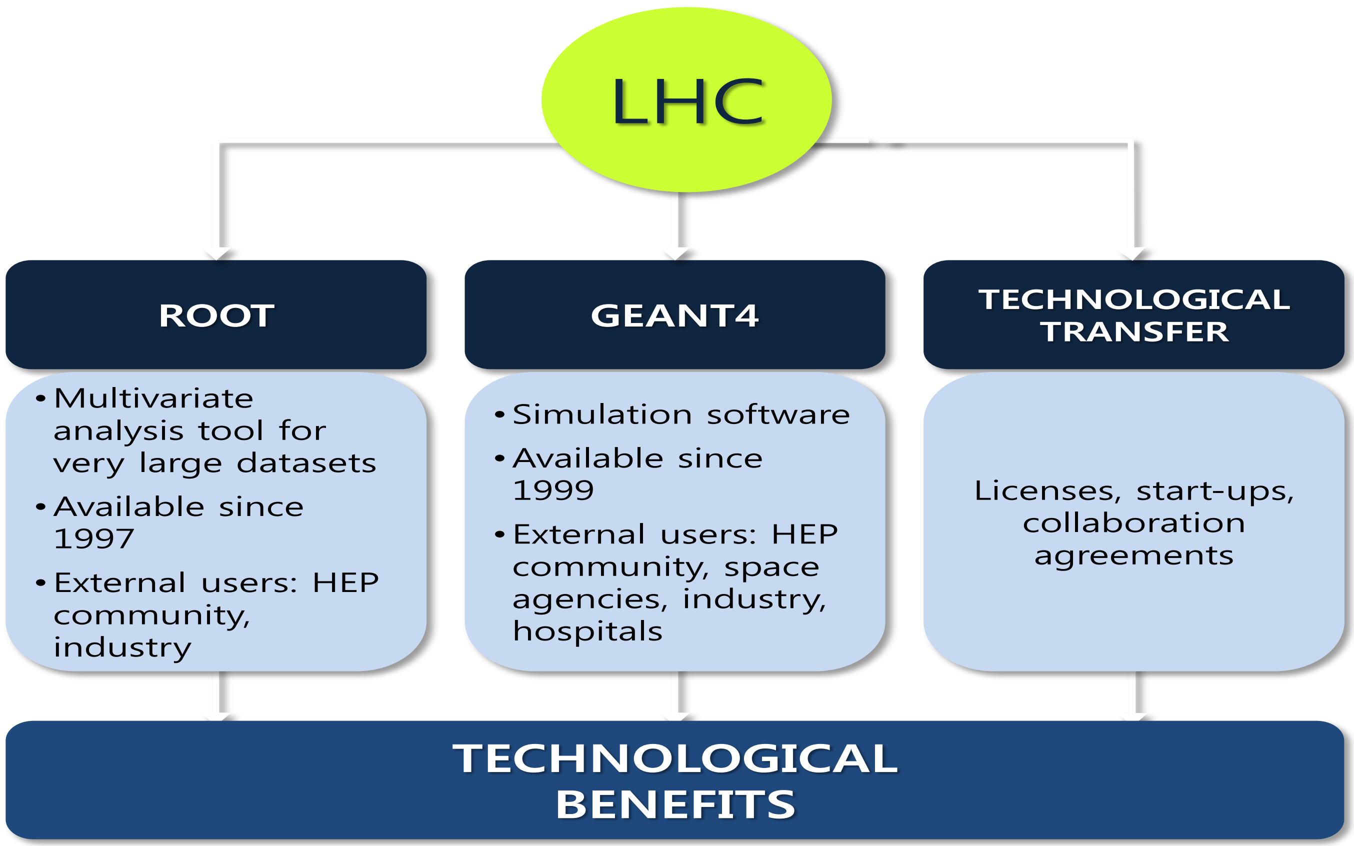
STEP 1. IDENTIFICATION OF HIGH-TECH ORDERS

ACTIVITY CODES FOR HIGH-TECH ORDERS

POWER CABLES AND CONDUCTORS	CASTING AND MOULDING (MANUFACTURING TECHNIQUES)
MAGNETS	FORGING (MANUFACTURING TECHNIQUES)
MEASUREMENT AND REGULATION	PRECISION MACHINING WORK
ELECTRICAL ENGINEERING	VACUUM PUMPS
ELECTRICAL ENGINEERING COMPONENTS	REFRIGERATION EQUIPMENT
ACTIVE ELECTRONIC COMPONENTS	GAS-HANDLING EQUIPMENT
PASSIVE ELECTRONIC COMPONENTS	STORAGE AND TRANSPORT OF CRYOGENS
ELECTRONIC MEASURING INSTRUMENTS	MEASUREMENT EQUIPMENT (VACUUM AND LOW-TEMPERATURE TECHNOLOGY)
POWER SUPPLIERS - TRANSFORMERS	LOW-TEMPERATURE MATERIALS
FUNCTIONAL MODULES & CRATES	VACUUM COMPONENTS & CHAMBERS
RF AND MICROWAVE COMPONENTS AND EQUIPMENT	LOW-TEMPERATURE COMPONENTS
CIRCUIT BOARDS	VACUUM AND LOW-TEMPERATURE TECHNOLOGY
ELECTRONICS	OPTICAL AND X-RAY EQUIPMENT
ELECTRONIC ASSEMBLY AND WIRING WORK	

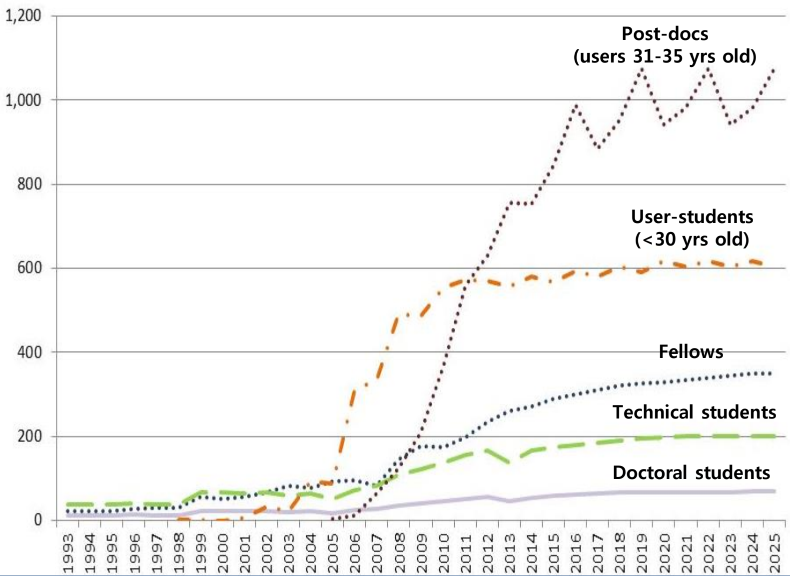
LHC: Technological Spillovers (2)

Benefits to software users



LHC: Human capital formation (1)

TYPES AND NUMBER OF PEOPLE BENEFITTING FROM TRAINING



TYPES AND QUANTITIES OF PEOPLE BENEFITTING FROM TRAINING

Variable	Number over the 1993-2025 period	Average staying at CERN
CERN fellows working on LHC	5,873	2 years
CERN technical students working on LHC	3,940	1 year
CERN doctoral students working on LHC	1,332	3 years
User-students working on LHC	14,225	3 years
Post-doc researchers (users) working on LHC	11,301	2 years
TOTAL	36,671	

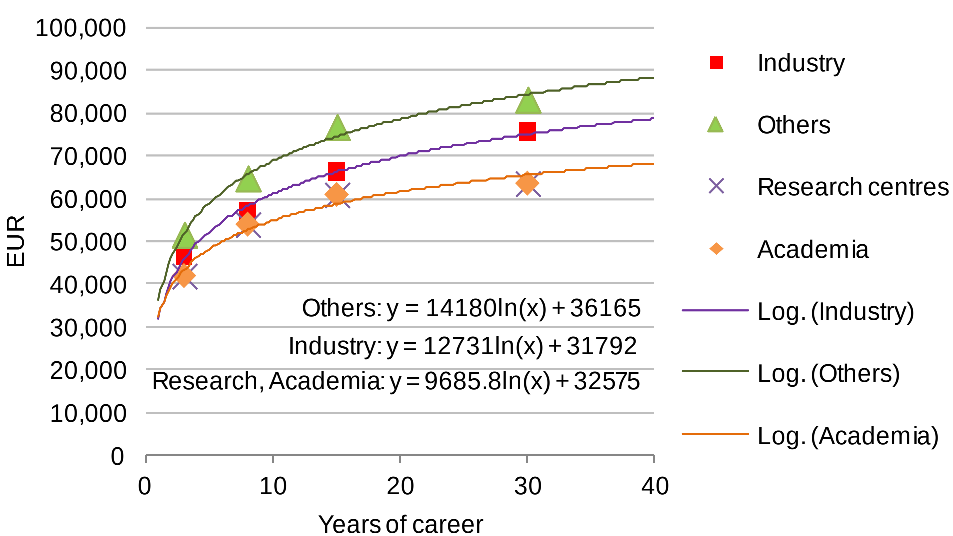
Sources: - CERN personnel statistics; - Interviews to CERN staff

Main assumptions: - Future number of beneficiaries; - Number of users-students and post-docs among users (assumed based on their age group); - Incoming number of user-students and post docs

ASSUMED DISTRIBUTION OF FORMER LHC STUDENTS BY PROFESSIONAL SECTOR

Sector	CERN fellows	CERN technical students	CERN doctoral students	User-students and post-docs
Industry	20%	45%	20%	20%
Others (computing, finance, public administration, …)	20%	45%	20%	20%
Research centres	30%	5%	30%	30%
Academia	30%	5%	30%	30%
TOTAL	100%	100%	100%	100%

ESTIMATION OF FUTURE AVERAGE SALARIES



DETERMINING THE RETURN TO SALARY DUE TO LHC TRAINING

Sector	SALARY EFFECT (1): CERN fellows, doctoral students, user students, post-docs	SALARY EFFECT (1): CERN technical students	SALARY BONUS FOR JOB EFFECT (2)
Research centres Academia Industry Others (computing, financial, …)	9.3%		2.5%

(1) Survey to 192 former LHC students (out of a total survey to 385 students and former students): declared salary impact of the experience at LHC on their current salary

(2) Own assumption based on survey results and Payscale salaries

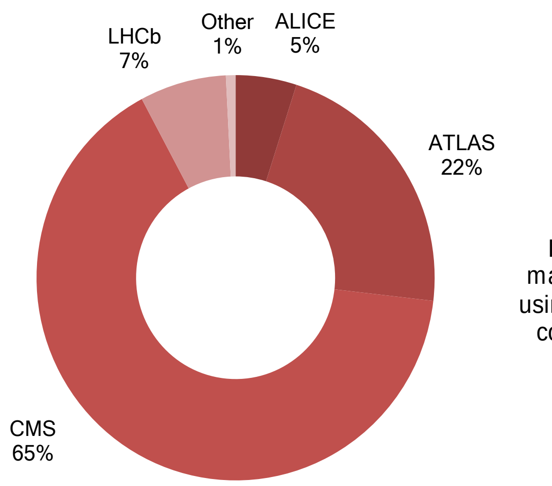
Main source:
Findings from the survey to LHC current and former students

Main assumptions:

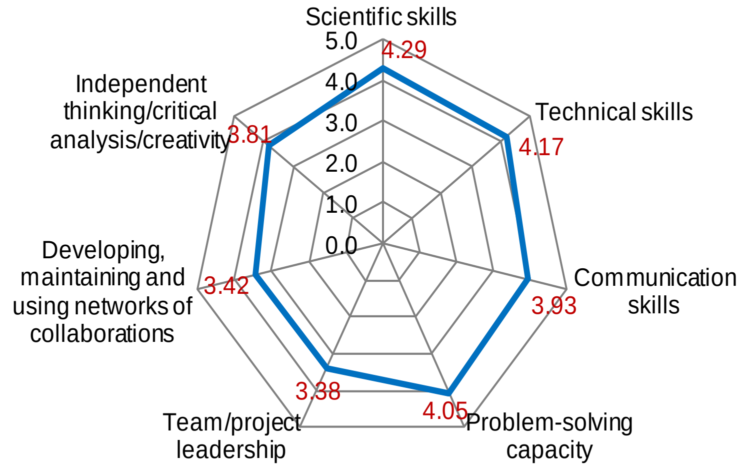
- Same economic return regardless of the professional sector and type of student
- Same return over the entire work career (40 yrs)

LHC: Human capital formation (2)

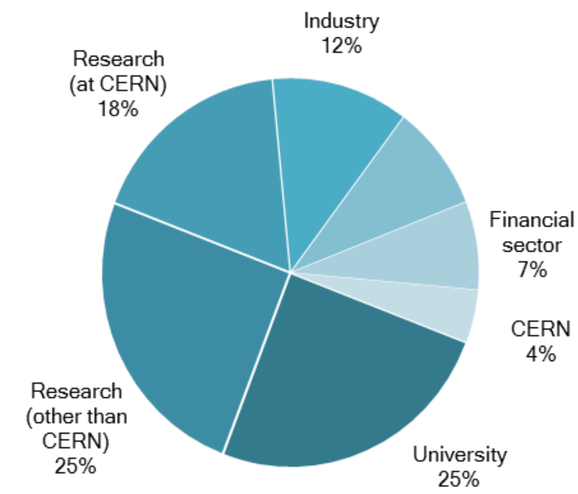
SHARE OF RESPONDENTS BY EXPERIMENT



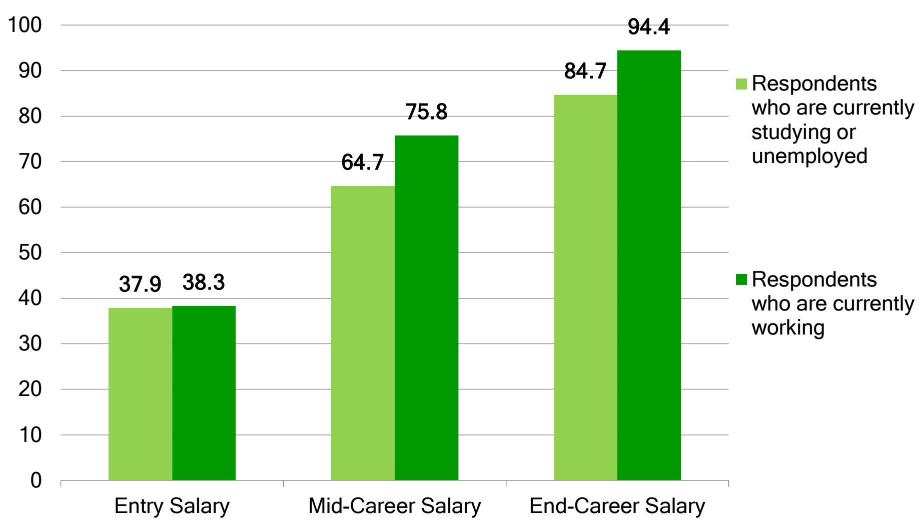
SKILLS IMPROVED THANKS TO THE LHC EXPERIENCE. AVERAGE JUDGEMENT



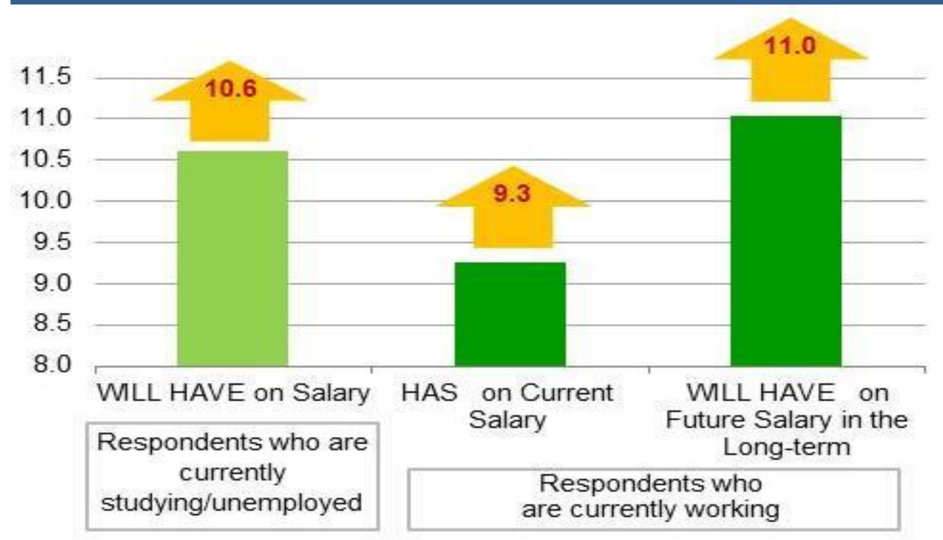
AN OVERVIEW OF CURRENT EMPLOYMENT SECTOR. SHARE OF RESPONDENTS



AVERAGE SALARY EVOLUTION: A COMPARISON BETWEEN THE TWO GROUPS OF RESPONDENTS (THOUSAND EUR)

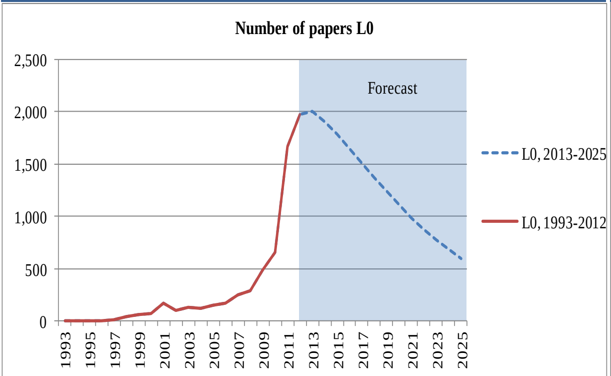


THE IMPACT OF LHC EXPERIENCE ON SALARY (%)

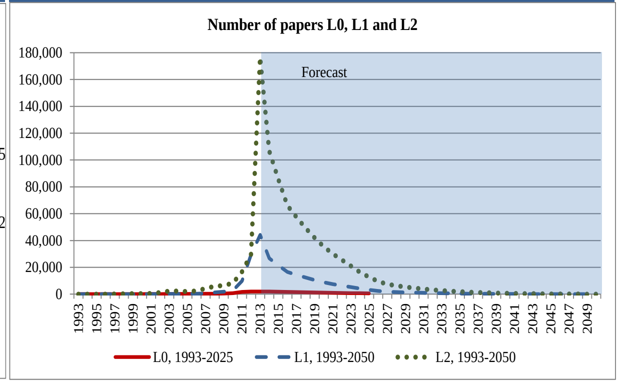


LHC: Knowledge Output

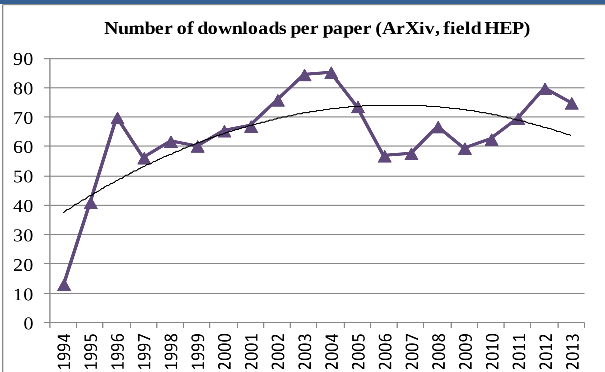
PAPERS PRODUCED BY LHC USERS (L0)

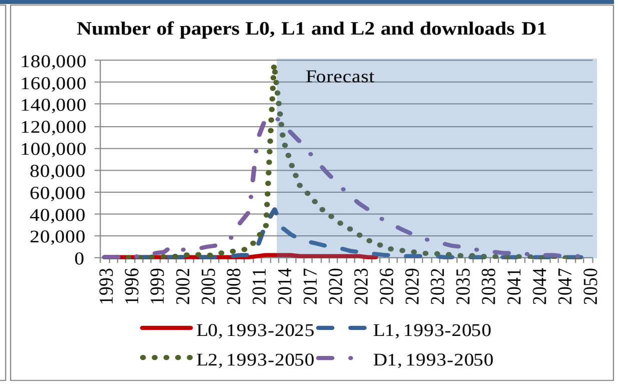


PAPERS PRODUCED BY NON-LHC USERS (L1 & L2)

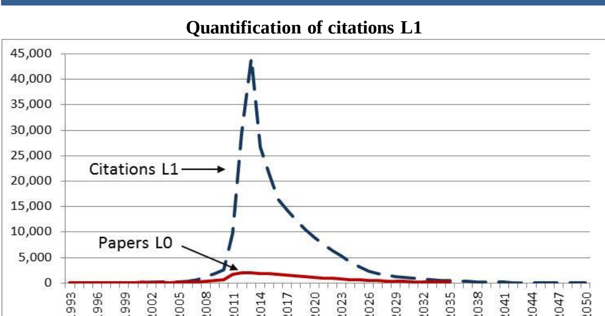


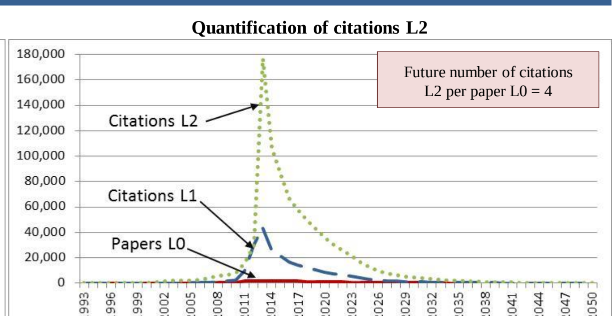
DOWNLOADS OF LHC PAPERS (D1)





TRACKING THE KNOWLEDGE OUTPUTS





Source: Preliminary scientometric analysis of INSPIRE database of papers and citations

VALUATION

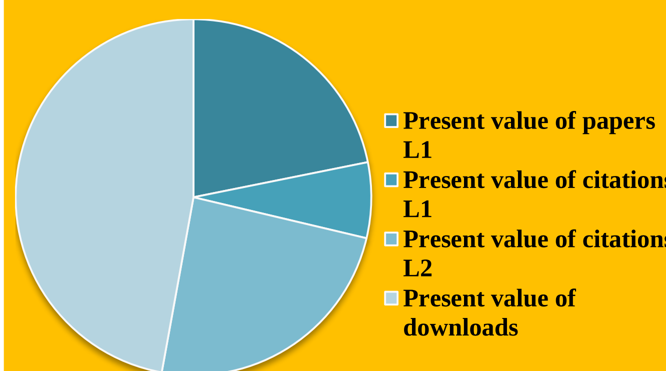
Unit economic value of papers L1

	Value	Source
Number of references in paper L1	35	Own assumption, based on an analysis of 41 research journals by Abt and Garfield (2002)
Share of time dedicated to research	65%	Own assumption. The remainder is for teaching and other non scientific activities
Number of paper (published and non) per year	3.5	Own assumption. It represents the number of papers to wich a scientist gives a real contribution
Average annual gross salary	59,289 €	Own elaboration based on PayScale data. It is the average salary for a scientists working in research centres and academia in the USA
Unit production cost per paper L1	315 € = (59,289 € * 65%/3.5/35)	Own estimation, based on the approach suggested by Florio and Sirtori (2014)

Unit economic value of citations and downloads

	Value	Source
Working hours per year	1,800 = 225 working days * 8 hours/day	Own assumption
Average hourly gross salary	33 € = 59,289/1,800	Own estimation
Hours per citation	3	Own assumption
Hours per download	3	Own assumption
Value of one citation L1 and L2	99 € = 33 € * 3	Own estimation, based on Florio and Sirtori (2014)
Value of one L0 paper downloaded but non cited	99 € = 33 € * 3	Own estimation, based on Florio and Sirtori (2014)

OUR RESULTS

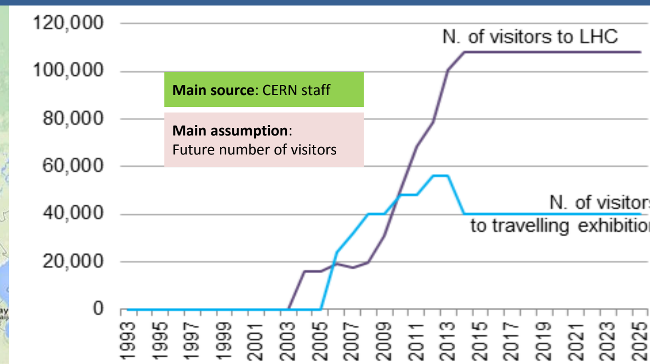


Except L_0

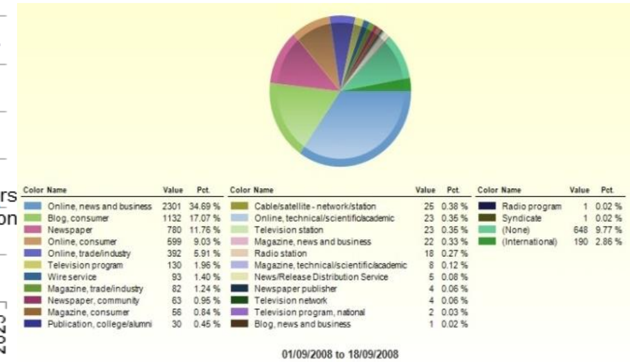
LHC: Cultural Effects

TRAVEL ZONES CONSIDERED

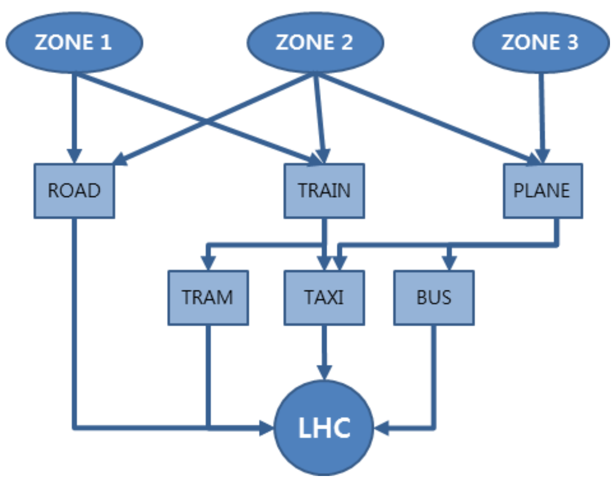
BENEFITS TO PERSONAL VISITORS: QUANTIFICATION OF VISITORS



MASS MEDIA BENEFITS: NEWS BY MEDIA CHART



VALUATION THROUGH THE TRAVEL COST METHOD

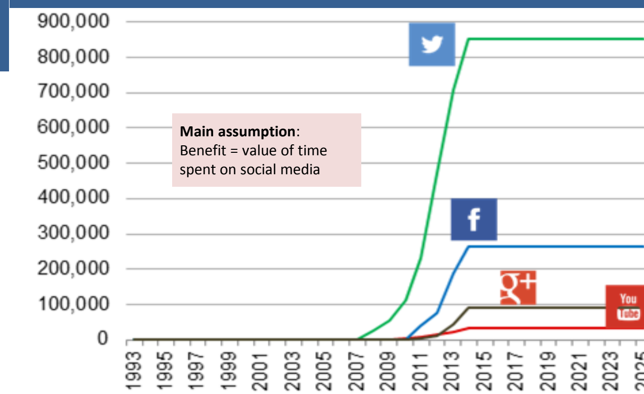


Main assumption:
- % of visitors by mode of transport
- Travel cost by zone

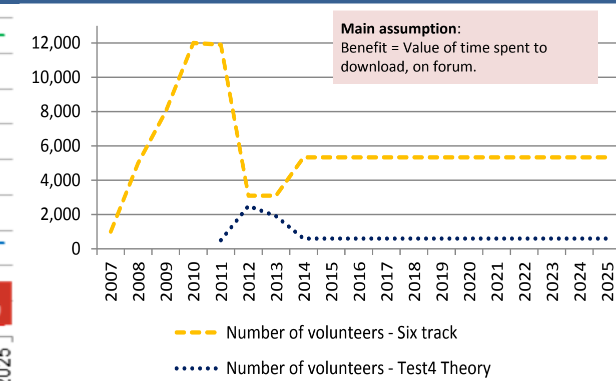
Source:
HEATCO values of travel time by modes of transport

Origin zone	Radius distance from CERN	Share of visitors	Source/ Assumption
Zone 1	500 km	24%	CERN
Zone 2	500-1,500 km	50%	Own assumption
Zone 3	Beyond 1,500 km	26%	Own assumption

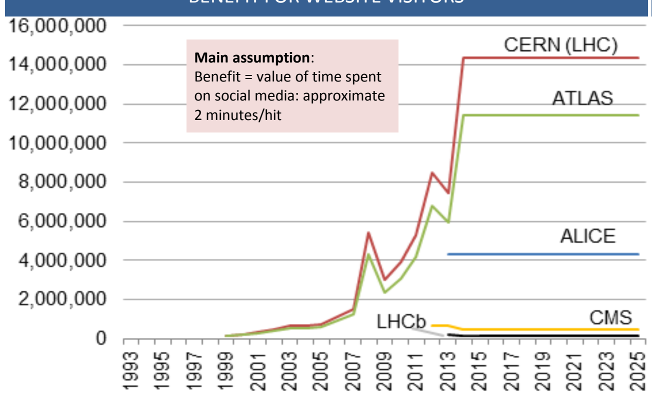
BENEFIT FOR SOCIAL MEDIA USERS



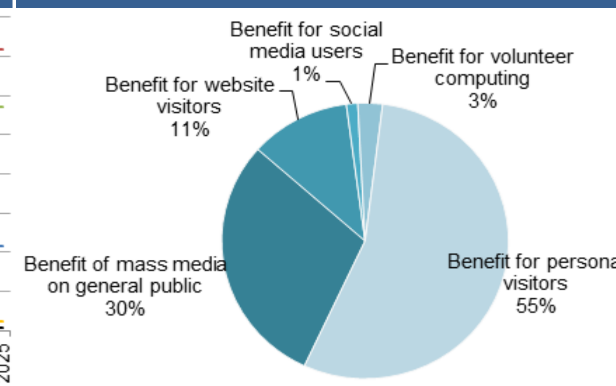
BENEFIT FOR VOLUNTEER COMPUTING



BENEFIT FOR WEBSITE VISITORS



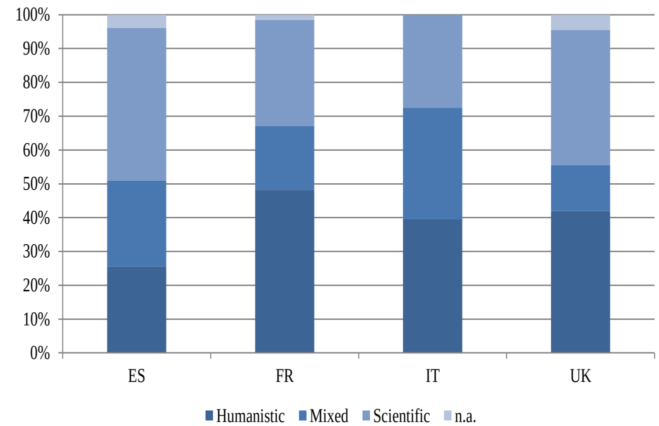
SHARE OF BENEFITS BY TYPE OF OUTREACH ACTIVITY



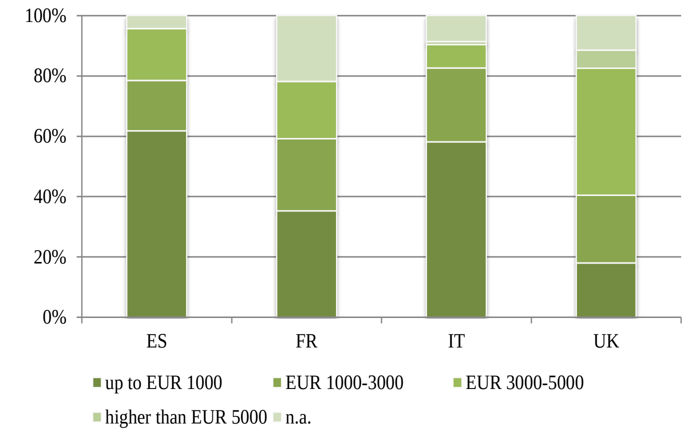
LHC: results from a contingent valuation

GENDER	Number
Female	*581*
Male	*446*
Total	*1027*
COUNTRY	**Number**
Italy	*422*
Spain	*204*
France	*201*
UK	*200*
Total	*1027*
YEARS	**Number**
19-25 years	*875*
26-30 years	*95*
31-35 years	*34*
Over 35 years	*20*
n.a.	*3*
Total	*1027*

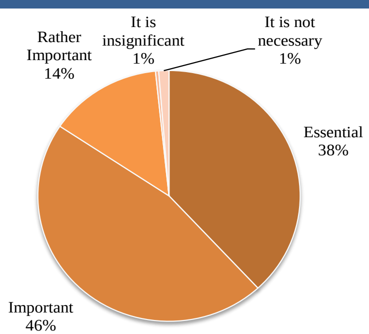
RESPONDENTS BY UNIVERSITY DEGREE



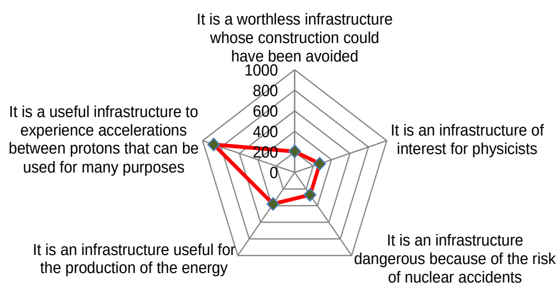
RESPONDENTS BY LEVEL OF HOUSEHOLD INCOME



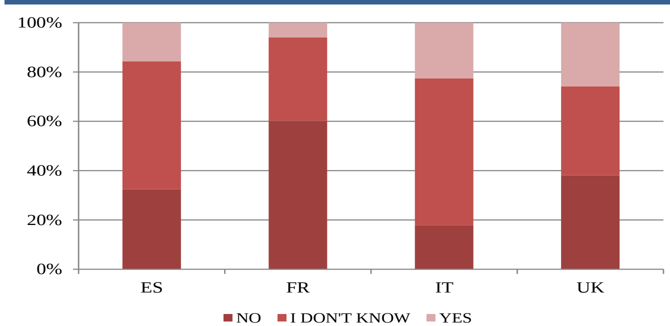
RATING THE IMPORTANCE TO FINANCE RDI



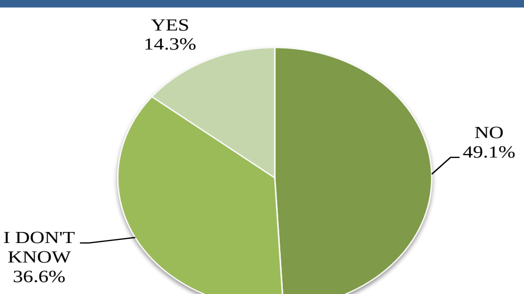
WHAT IS THE UTILITY OF THE LHC



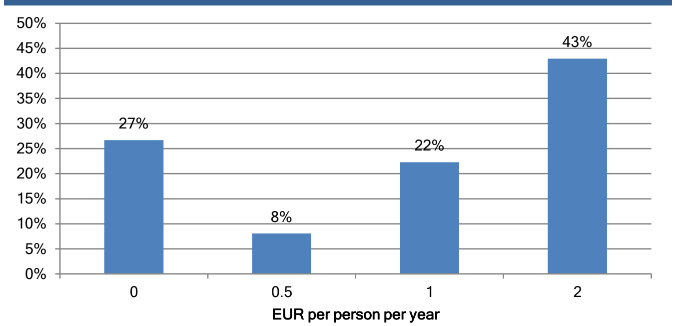
WILLINGNESS TO PAY FOR LHC



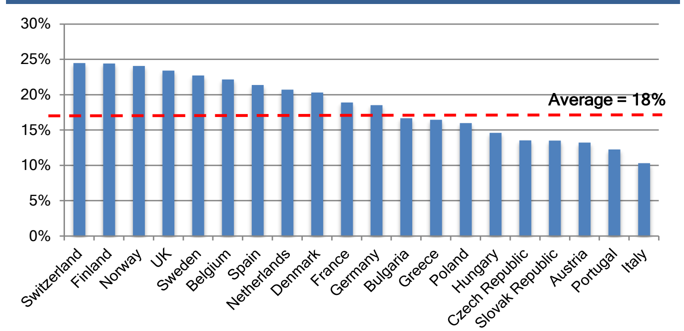
WTP TO PAY *UNA TANTUM*



AVERAGE ANNUAL WTP



SHARE OF ADULT POPULATION (18-74 YEARS OLD) WITH AT LEAST TERTIARY EDUCATION

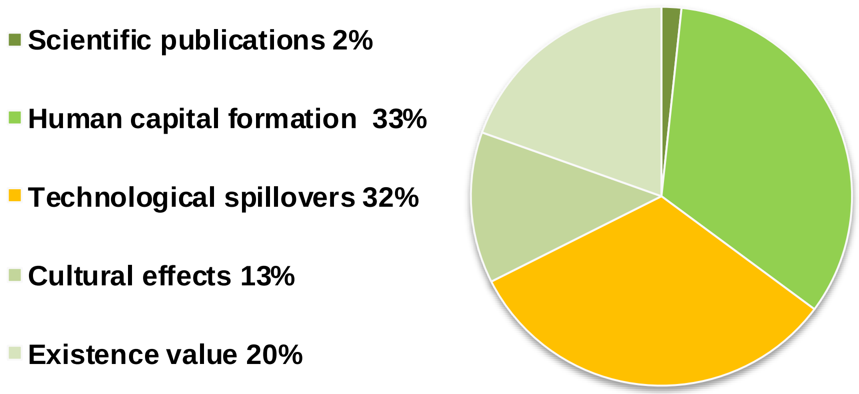


LHC: CBA results (1)

LHC: summary of costs and benefits (Billion, EUR)	
COSTS:	13.5 ± 0.4
USE BENEFITS:	
Knowledge Formation	0.3 ± 0.1
Human Capital	5.5 ± 0.3
Technological Spillovers	5.3 ±1.7
Cultural	2.1 ± 0.5
NON-USE BENEFITS:	
Existence Value	3.2 ± 1.0

- **Human capital, technological spillovers, cultural + existence value each give about 33% of benefits** (publications are negligible)
- **Uncertainty largest on technological spillovers**
- More than **90% chance of positive** NPV

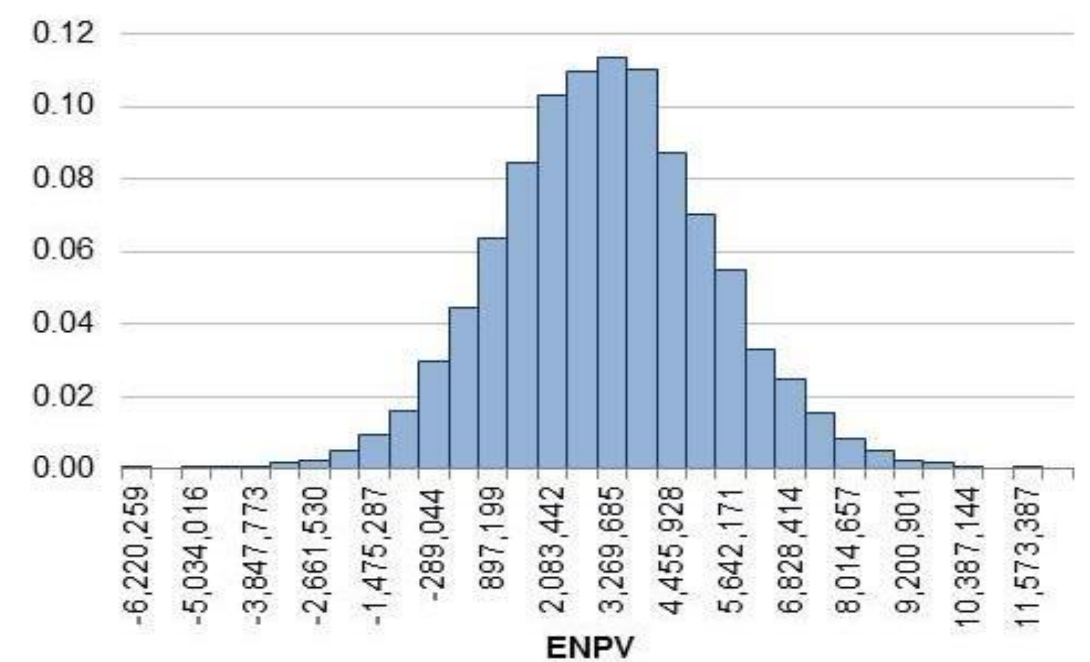
TOTAL MEASURED BENEFITS



LHC: CBA results (2)

ESTIMATED PARAMETERS OF DISTRIBUTION	
Mean	2,855,528
Median	2,825,860
Standard Deviation	2,134,763
Minimum	-6,220,259
Maximum	11,573,387
Estimated probabilities	
Pr. ENPV ≤ 0	0.086
Montecarlo error	
3 ϭ 10,000	0.02

PROBABILITY DENSITY FUNCTION



CNAO
CASE STUDY

What is hadrontherapy?

- **Hadrontherapy is an innovative cancer radiotherapy modality based on nuclear particles** (protons, neutrons and light ions such as carbon ions) for treatment of early and advanced tumors
- At present, 39 facilities are in operation worldwide, 27 are under construction and 11 in the design phase
- Since 1990 (Loma Linda, California) around **100,000 patients** worldwide have been **treated with protons**
- Around **10,000 patients** have been **treated with ions**, generally carbon
- Carbon ions treatment is still an experimental treatment
- At present, there are no commercial machines for hadrontherapy with carbon ions

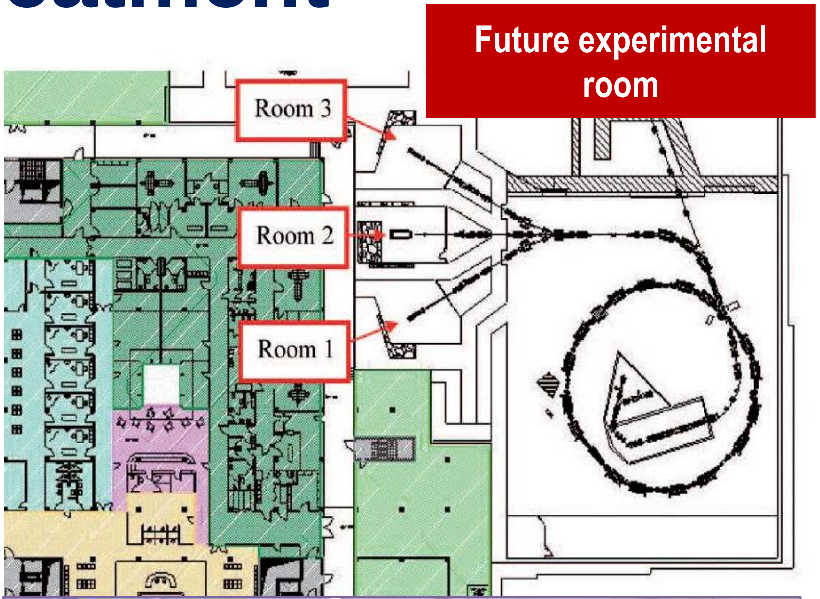
Economic aspect

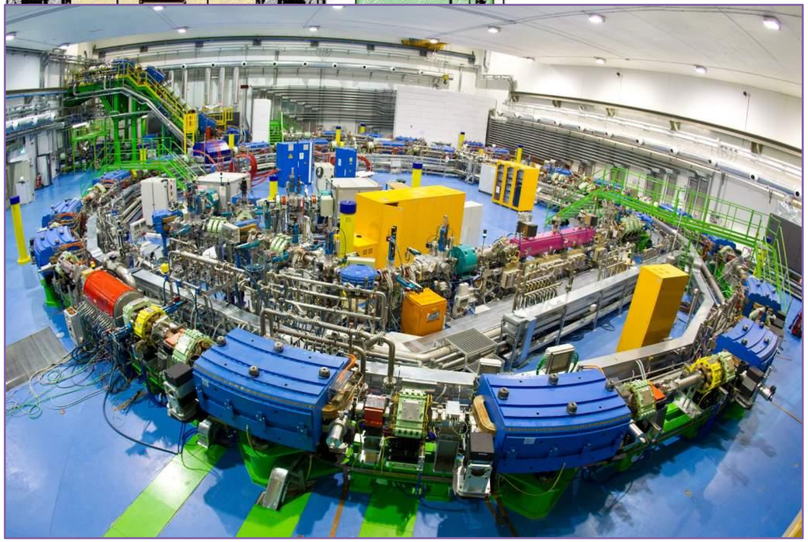
- Conventional radiotheraphy: ~ EUR 6,000
- Hadrontheraphy: ~ EUR 20,000

Is it worth for the society financing such Applied Research Infrastructure?

CNAO - National Hadrontherapy Center for Cancer Treatment

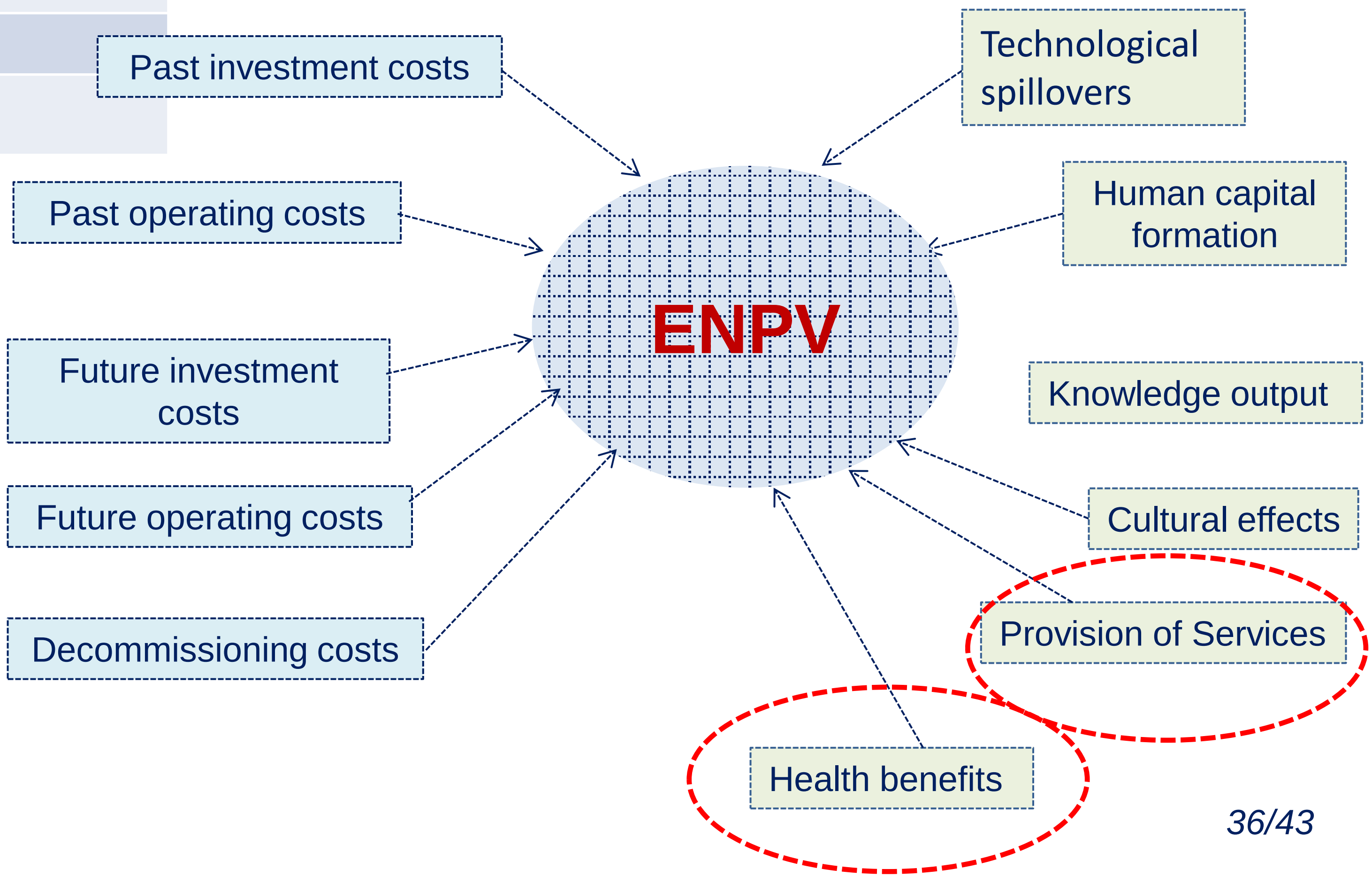
- Outside the synchrotron there are 4 extraction lines (3 horizontal and 1 vertical) leading the extracted beam into 3 treatment rooms.
- In each room it is possible to perform proton and carbon ion therapy.
- Active scanning.
- An experimental beam line with a dedicated room is under construction since July 2014 in collaboration with INFN.





The key parameters and ingredients of the CBA of CNAO

TIME HORIZON	30 years: 2001 - 2031
UNIT OF ANALYSIS	The hall hosting the particle accelerators and the other areas functional to the proper functioning of the clinical facility
SOCIAL DISCOUNT RATE	3% in real terms (adopted by the EC CBA Guide, 2014)
SHADOW PRICES	Proxied by marginal WTP or marginal costs
COUNTERFACTUAL	Do-nothing
Non-use benefits	assumed 0
NEGATIVE EXTERNALITIES	assumed 0

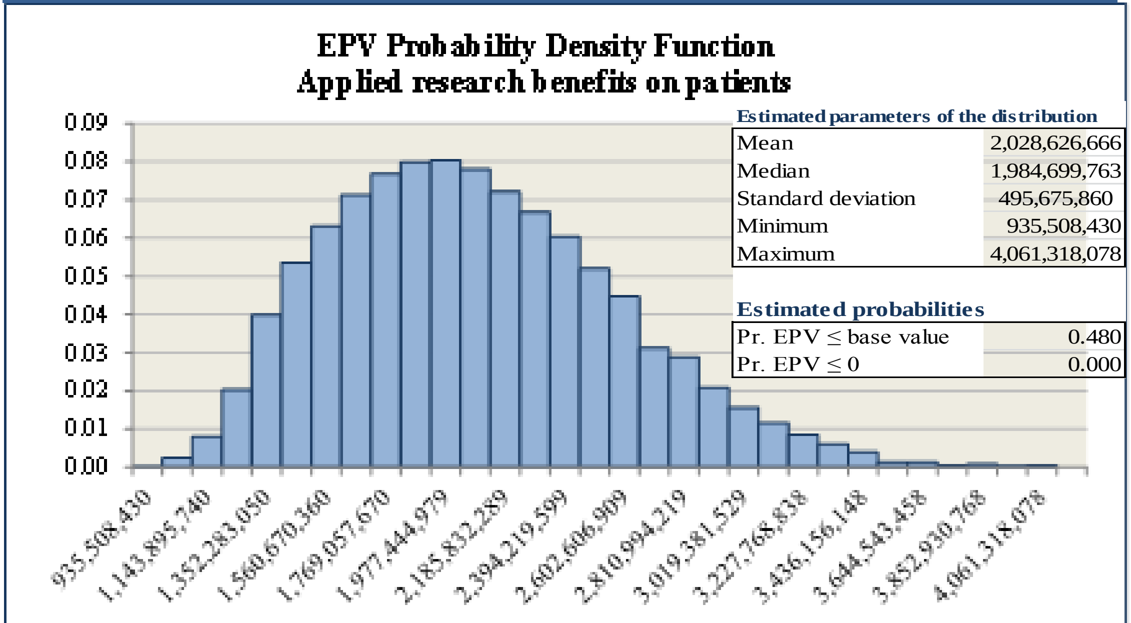


CNAO: Estimation of health benefits

$$A = \sum_{t}^{T} \frac{\sum_{p}^{P} \sum_{i}^{I} (N_{p,i} * E_p) * (X_{pi} * VOLY_i) * Q_p}{(1+3\%)^t}$$

N: number of patients
E: share of patients who gain additional years of life compared to the identified counterfactual
X: number of life years gained
VOLY: Value of Statistical Life Years
Q: coefficient capturing the increased quality of life
p (1, ..23): clinical protocol
i (1, ..6): age class
t (1, ..30): year of time horizon

Probability distribution of applied research benefits on patients (Euros)



Type 1 – FULL RECOVERY
Marginal benefit by protocols

2	No alternative	73%
3	No alternative	33%
9	Surgery + photon therapy	45%
10	Surgey	21%
11	No alterative*	45%
12	No alterative*	14%
15	Surgery + photon therapy	30%
16	Photon therapy	43%
13	No alterative*	33%
19	Photontherapy	36%

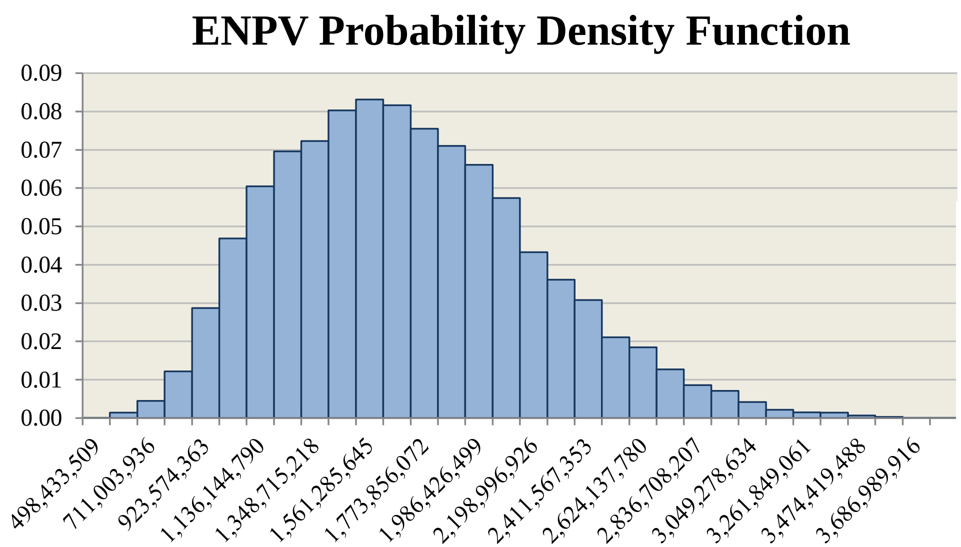
Type 2 – INCREASE IN LIFE EXPECTANCY
Marginal benefit by protocols

# of protocol	Clinical alternative	Marginal percentage of patients who fully recover compared to the counterfactual	Number of life years gained with respect to the counterfactual
6	No alternative for advanced tumours	15%	5
8	No alterative	43%	3
14	No alterative*	68%	0.5
18	Palliative chemotherapy	40%	2
20	No alterative	43%	3
22	Surgey + photon therapy	10%	5
23	Photontherapy*	35%	5

Type 3 – BETTER QUALITY OF LIFE
Marginal benefit by protocols

# of protocol	Clinical alternative	Marginal percentage of patients who fully recover compared to the counterfactual	Number of life years gained with respect to the counterfactual	Quality of life adjustment factor*
7	No alterative	100%	1	0.3
21	Surgey	100%	15	0.3

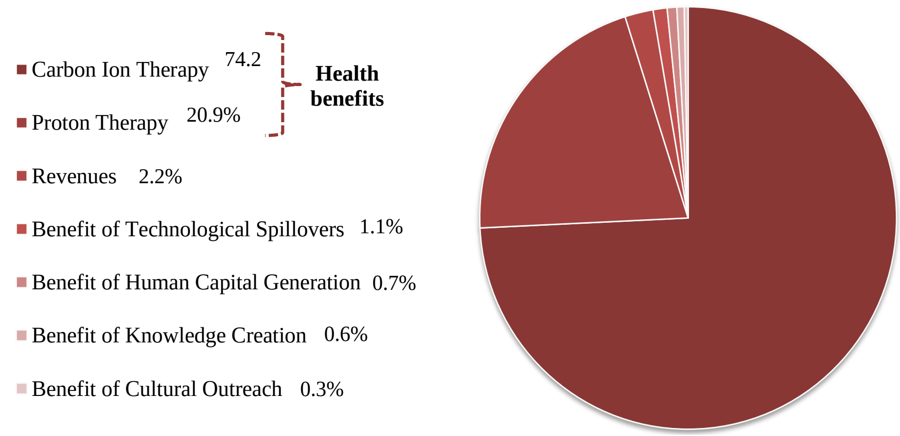
CNAO: CBA Results

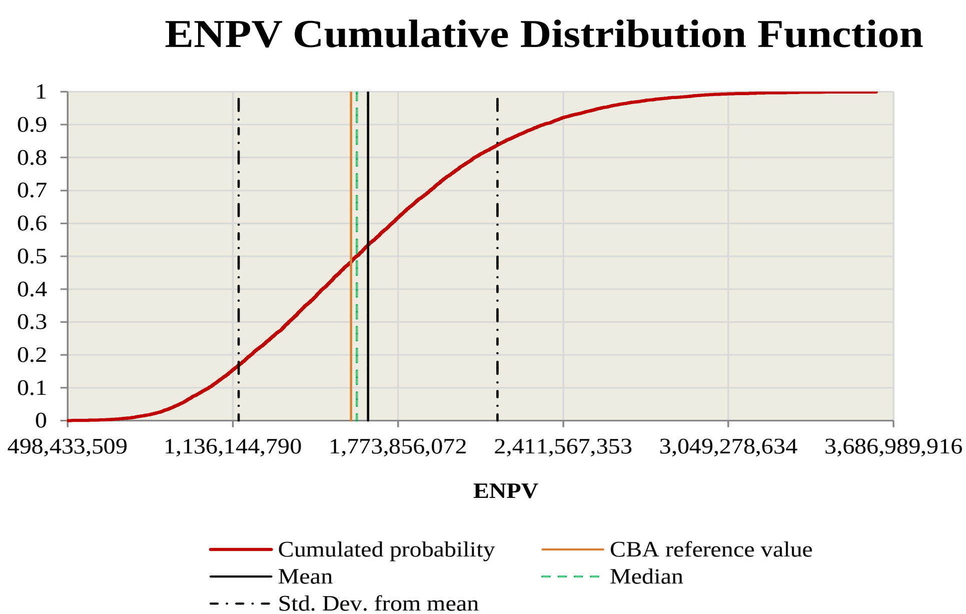


PROBABILITY DISTRIBUTION OF

THE CNAO NET PRESENT VALUE

Own estimate of the Present Value PDF resulting from a Monte Carlo simulation (10,000 random extractions)





ESTIMATED PARAMETERS OF DISTRIBUTION	
Mean	1,658,358
Median	1,615,046
Standard Deviation	499,225
Minimum	498,433
Maximum	**3,686,989**
Estimated probabilities	
Pr. ENPV ≤ 0	0.000

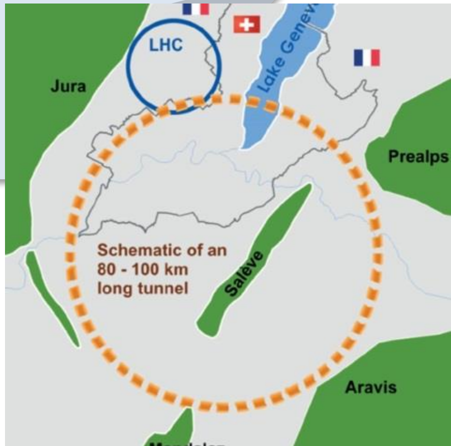
Values in Thousands EUR, 2013

Our findings

- There is an **increasing need** of evaluation of socio-economic impact of RDI infrastructure.
- Until now **limited progress** in finding a **shared methodology**.
- We have proposed a **CBA model rooted** in applied welfare economics theory and international experience.
- We have been able to show that the model could be applied to **pilot case studies** (LHC and CNAO).

Future Research

- **Testing the model** on other Research Infrastructures
- Forecasting technological spillovers with a **control group of firms** (non-CERN suppliers)
- Estimating human capital effects with **econometric 'treatment' techniques**
- Developing a **forecasting model for media impact** of outreach
- Expanding the **contingent valuation of willingness to pay** for discoveries
- **High Luminosity - LHC**
- Applying the model to the **Future Circular Collider**



Special Issue on:

The social impact of Research Infrastructures at the frontiers of science and technology

Guest editors: Chiara Del Bo, Massimo Florio and Stefano Forte

- **The social impact of research infrastructures at the frontier of science and technology: The case of particle accelerators**. Editorial introduction Del Bo, C., Florio, M., Forte, S.
- **Particle accelerators at CERN: from the early days to the LHC and beyond**. Evans, L.
- **The Probability of Discovery**. De Roeck A.
- **On Lessons from Energy and Environmental Cost-Benefit Analysis.** Johansson P. O.
- **The rate of return to investment in R&D: the case of Research Infrastructures.** Del Bo Chiara F.
- **Social Benefits and Costs of Large Scale Research Infrastructures.** Florio M. and Sirtori E.
- **Some remarks concerning the Cost/Benefit Analysis applied to LHC at CERN**. Schopper H.
- **Forecasting the Socio-Economic Impact of the Large Hadron Collider: a Cost-Benefit Analysis to 2025 and Beyond.** Florio M., Forte S. and Sirtori E.
- **Cost-Benefit Analysis of applied research infrastructure. Evidence from health care.** Battistoni, G. et al.
- **Grenoble “GIANT Territorial Innovation Models: Are Investments in Research Infrastructures Worthwhile?** Scaringella L. et al.
- **Scientific Effects of Large Research Infrastructures in China.** Chen K. et al.
- **Knowledge Transfer at CERN.** Nilsen V. et al
- **Research infrastructures in the LHC era: a scientometric approach.** Carazza, S. et al.

Further References

- Camporesi, T. Catalano, G., Florio, M. and Giffoni, F., (2016), **A "LHC Premium" for Early Career Researchers? Perceptions from within**, https://arxiv.org/ftp/arxiv/papers/1607/1607.01941.pdf

- Catalano, G., Florio, M. and Giffoni, F., (2016), Willingness to pay for basic research: a contingent valuation experiment on the large hadron collider, https://arxiv.org/ftp/arxiv/papers/1603/1603.03580.pdf

- Florio, M., Forte, S., Pancotti, C., Sirtori, E., Vignetti, S. (2016), **Exploring cost-benefit analysis of research, development and innovation infrastructures: an evaluation framework**, https://arxiv.org/ftp/arxiv/papers/1603/1603.03654.pdf

- Florio, M., Forte, S., Sirtori, E. (2016), **Forecasting the Socio-Economic Impact of the Large Hadron Collider: a Cost-Benefit Analysis to 2025 and Beyond,** https://arxiv.org/pdf/1603.00886v1.pdf

THANK YOU

massimo.florio@unimi.it