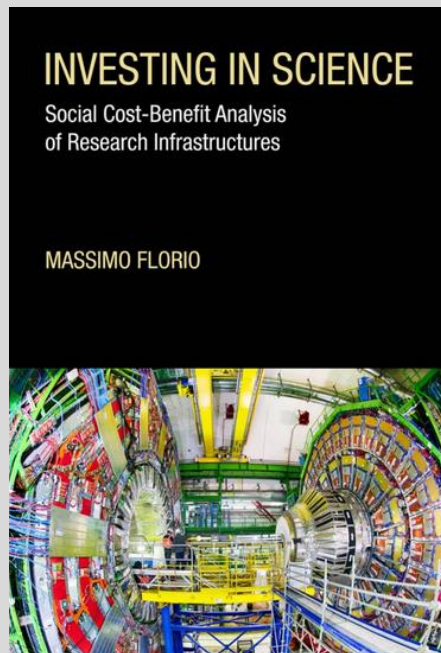


RESEARCH INFRASTRUCTURES: A NEW PARADIGM OF KNOWLEDGE PRODUCTION

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University of Milan



November 29, 2019
ECOOM, Brussels

OUTLINE

- Two paradigms of large-scale knowledge production
- The social value of Research Infrastructures (RIs)
- Conceptual framework
- A visual tour of case studies
- RIs as publication factories and human capital
- Learning hubs for hi-tech firms and Big Data
- From science to innovation
- The value of fun
- Further question: RIs as new public enterprises
- Conclusions

SCIENCE AND R&D

WORLD*:

1.7 trillion
R&D expenditure

7.8 million
researchers

0.1%
world population

218k
GERD per researcher

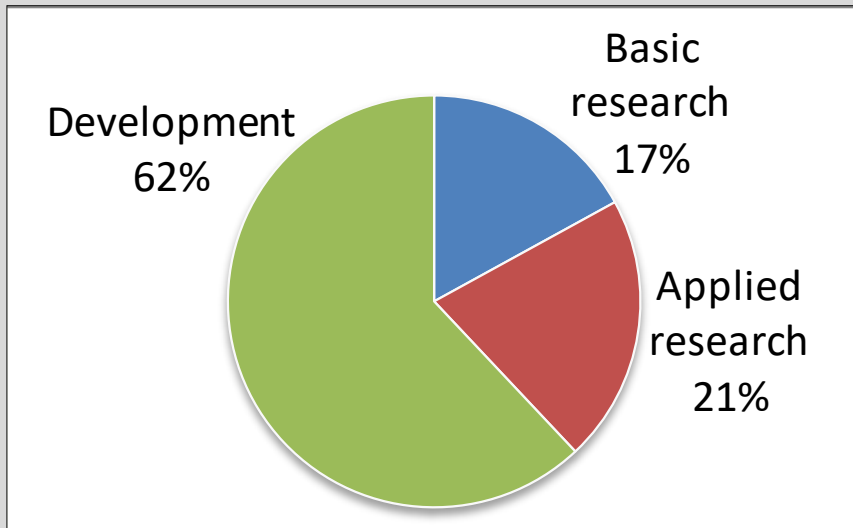
500 billion USD
R&D USA

409 billion USD
China

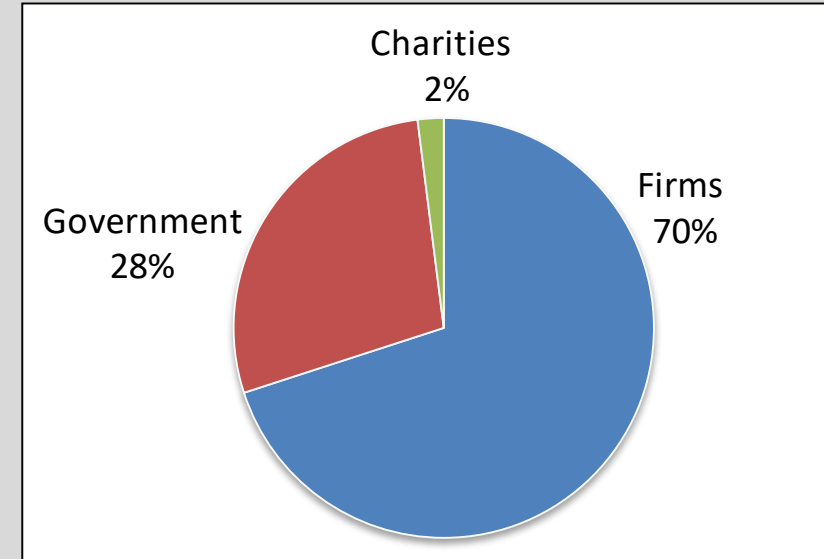
386 billion USD
EU 28 Area

405 billion USD
Rest of the world

OECD AREA:



Government
funding: USD
315 billion or
USD 246
p.c./year to
R&D.



- All values are in current USD.
- **Sources:** UNESCO and OECD 2015-2017

TWO PARADIGMS OF LARGE-SCALE KNOWLEDGE PRODUCTION

THE SIX CORE INGREDIENTS:

RESEARCH INFRASTRUCTURE

Identification of priorities within the scientific community (**bottom-up**)

International coalitions of funders (limited national ownership)

Flexible accessibility to common resources by multiple users and shared governance

Cosmopolitan human capital incubator

Open technological and scientific hubs and Big data generators

Public involvement essential to justify funding

BIG SCIENCE

Association with defense and military-industrial complex of the major powers (**top-down**)

Government budgets secure the **national ownership** of science

Rigid mission and governance

Recruitment of best minds but **politically loyalty** required

Secrecy on technologies, research methods and results

Selective exposure to **apologetic** press coverage

TWO PARADIGMS OF LARGE-SCALE KNOWLEDGE PRODUCTION

RI DEFINITION

- «Research infrastructures are **facilities, resources, and services**
 - used by the **research communities** [...]
 - may be used **beyond research, e.g. for education or public services**
 - **major scientific equipment**
 - knowledge-based resources such as collections, archives, or **scientific data**
 - **e-infrastructures**
 - ‘**single-sited**’, ‘**virtual**’ or ‘**distributed**’ » (European Commission 2017)
- ... and **mobile** as probes, satellites, oceanographic vessels, etc.

Guess:

300 major RIs in
EU

300,000 scientists in
EU

1 million scientists are RI users
World

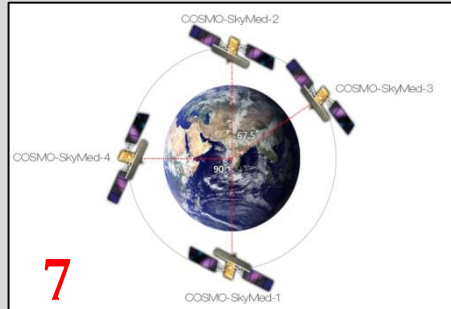
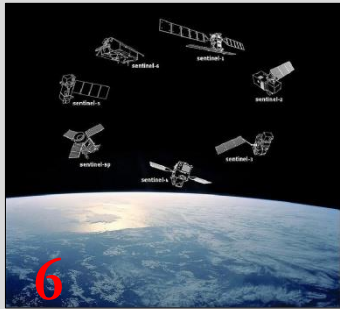
1032 RIs in the ESS database and see also Del Bo (2016)

https://portal.meril.eu/meril/static/static_documents

A VISUAL TOUR OF RI CASE STUDIES



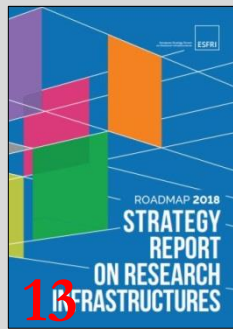
- 1: Alba Synchrotron, Barcelona
- 2: Diamond Light Source, Didcot (UK)
- 3: CNAO Hadron Therapy, Pavia
- 4: Large Hadron Collider, CERN



- 5: Square Kilometre Array, ZA and AUS
- 6: Copernicus Sentinels
- 7: COSMO SkyMed

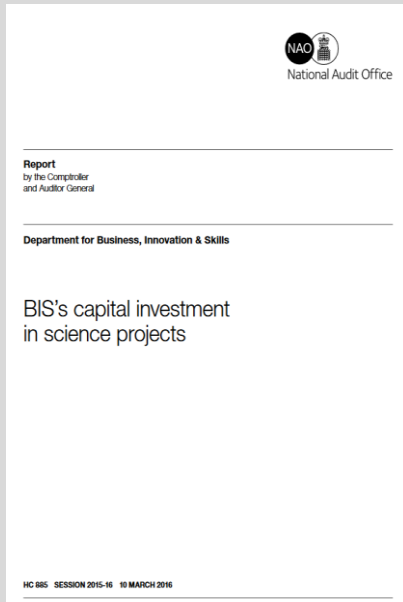
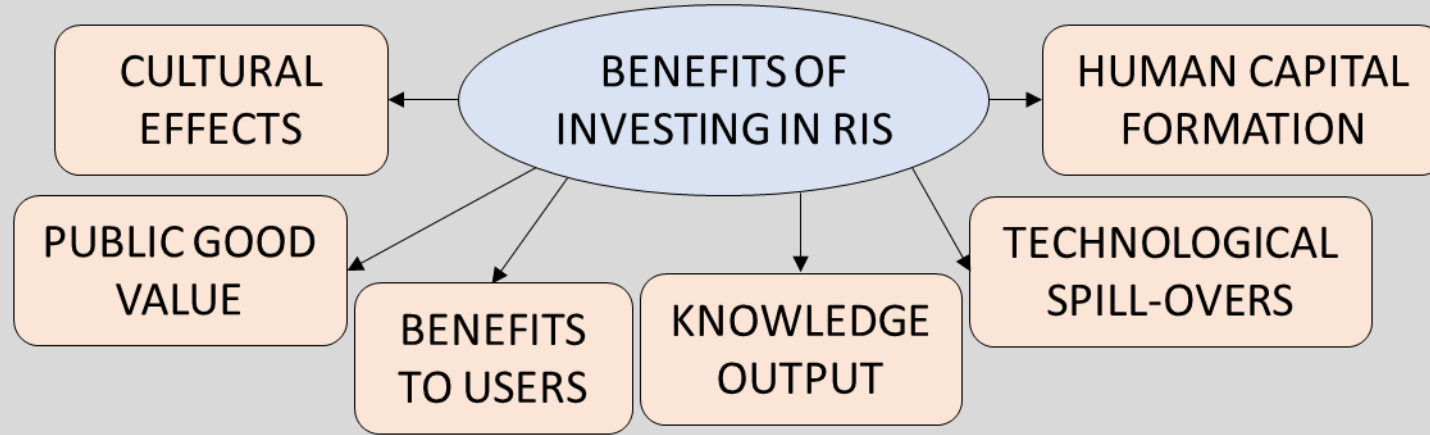


- 8: ELIXIR Research Institute
- 9: EMBL-EBI
- 10: Broad Institute of MIT and Harvard
- 11: NIH

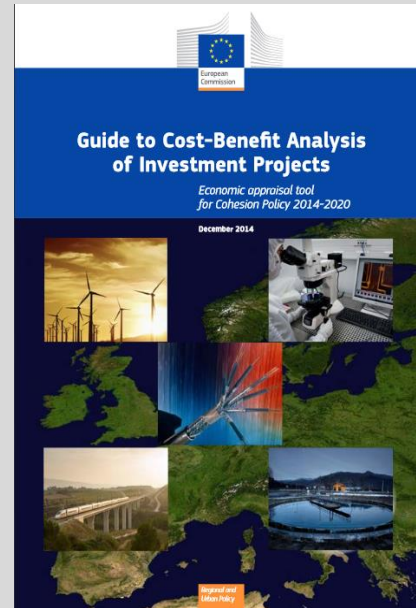


- 12: Department of Energy, US National Laboratories
- 13: ESFRI Roadmap

WHY CBA FOR RIS?



CBA is cited by National Audit Office Report, *BIS's capital investment in science projects*, (2016)



Recommended for RIs that receive co-funding by EU



Mentioned by ESFRI roadmap

THE CBA MODEL FOR RIS

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

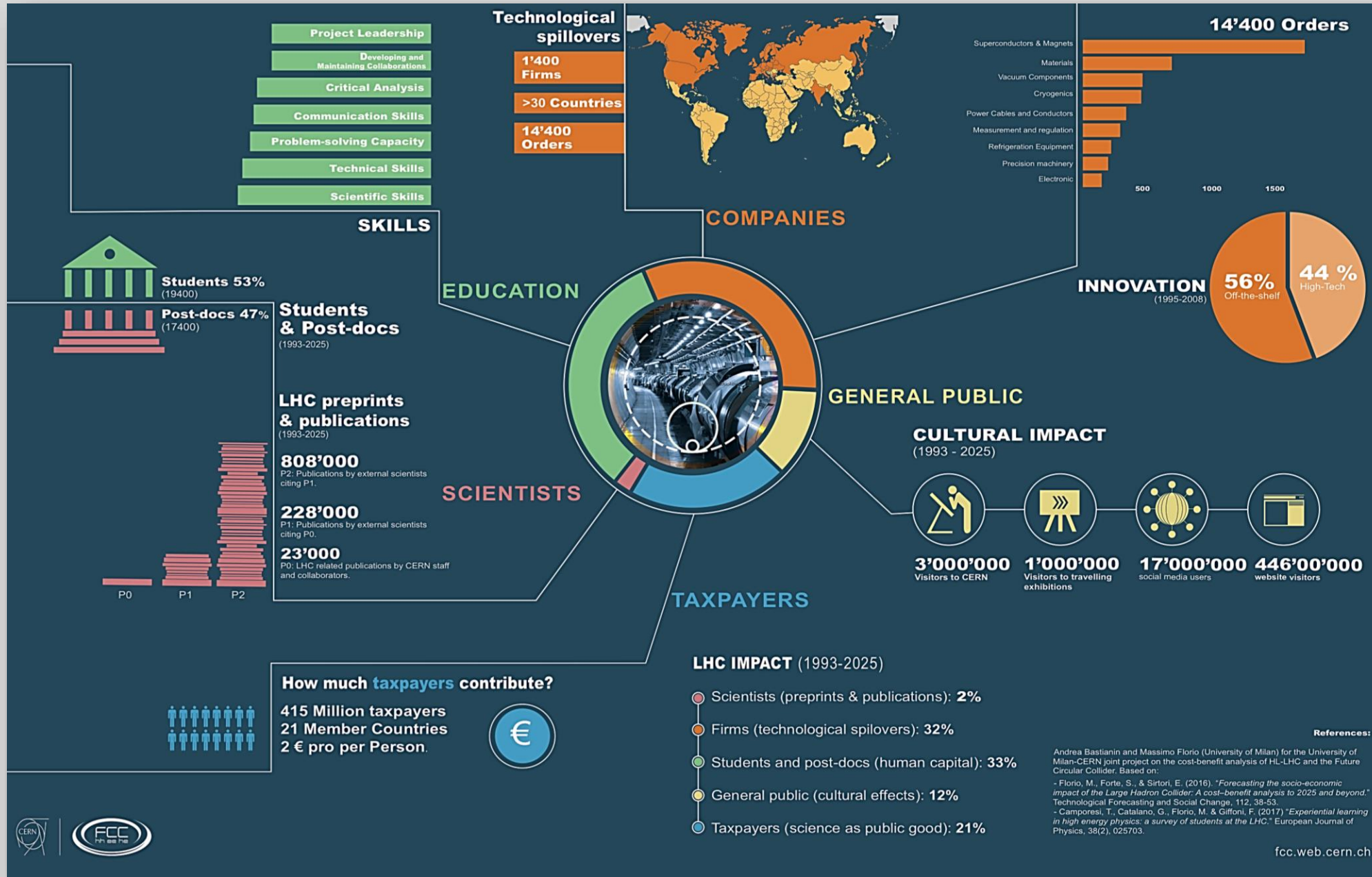
PV_{B_u} = present value of use-benefits

B_n = non use-benefits

PV_{C_u} = present value of costs

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).

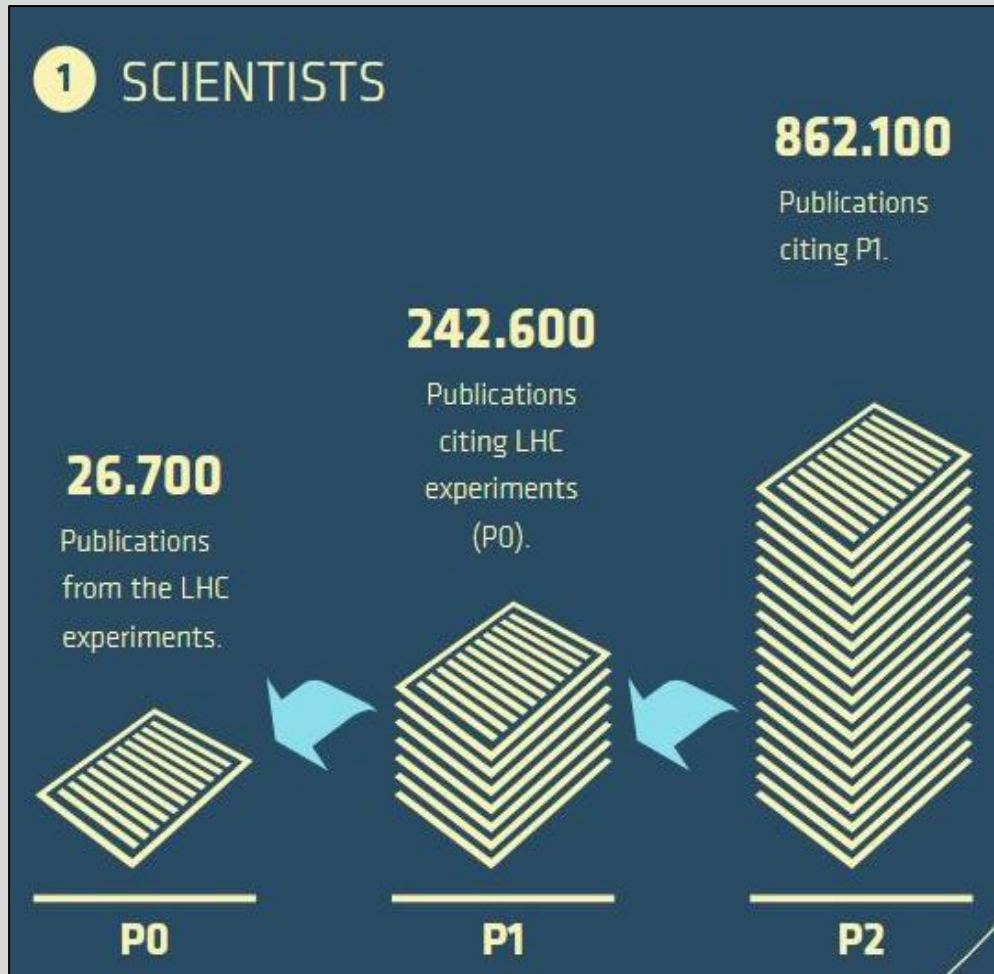
CBA – CERN LHC



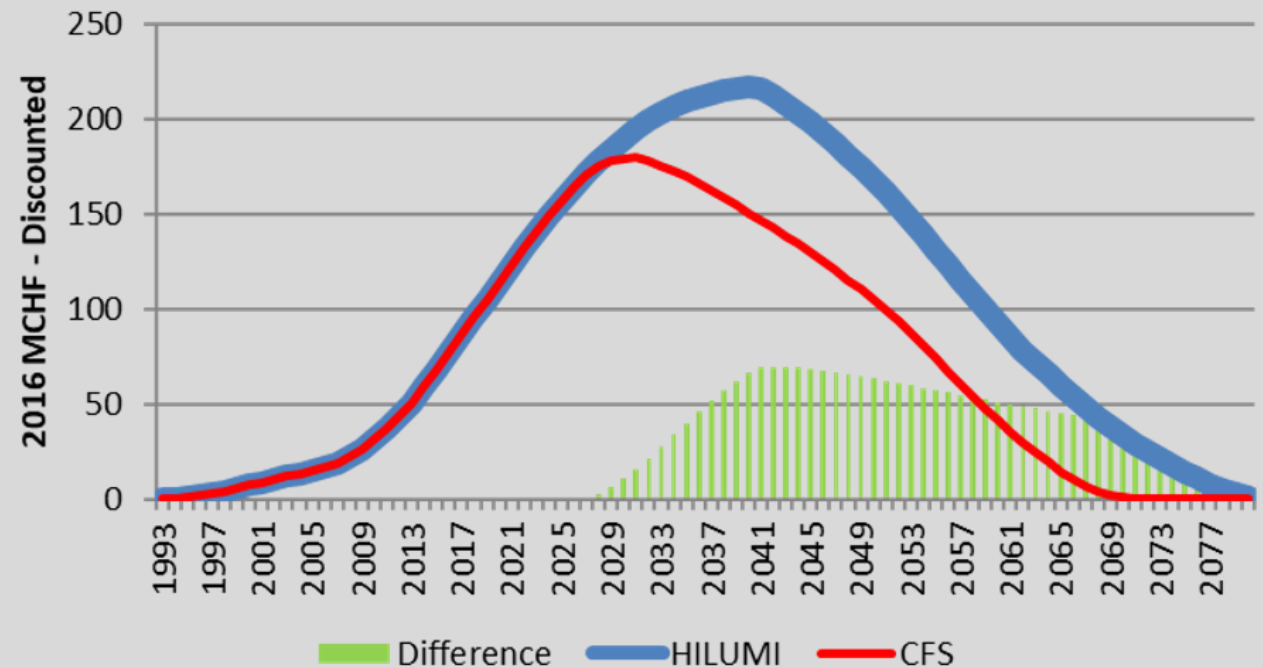
- Time: 1993 – 2025
- Costs: € 13.5 B
- Benefits: € 16.4 B
- NPV: € 2.9 B
- B/C ratio: 1.2
- * cost of scientific personnel excluded

PUBLICATION FACTORIES AND HUMAN CAPITAL

1993 – 2038



Benefits to students and post-docs - 1993-80



- Social value of publication *per se* modest (MSV = marginal cost)

BENEFITS TO FIRMS

THE PROCUREMENT ACTIVITY OF CERN*

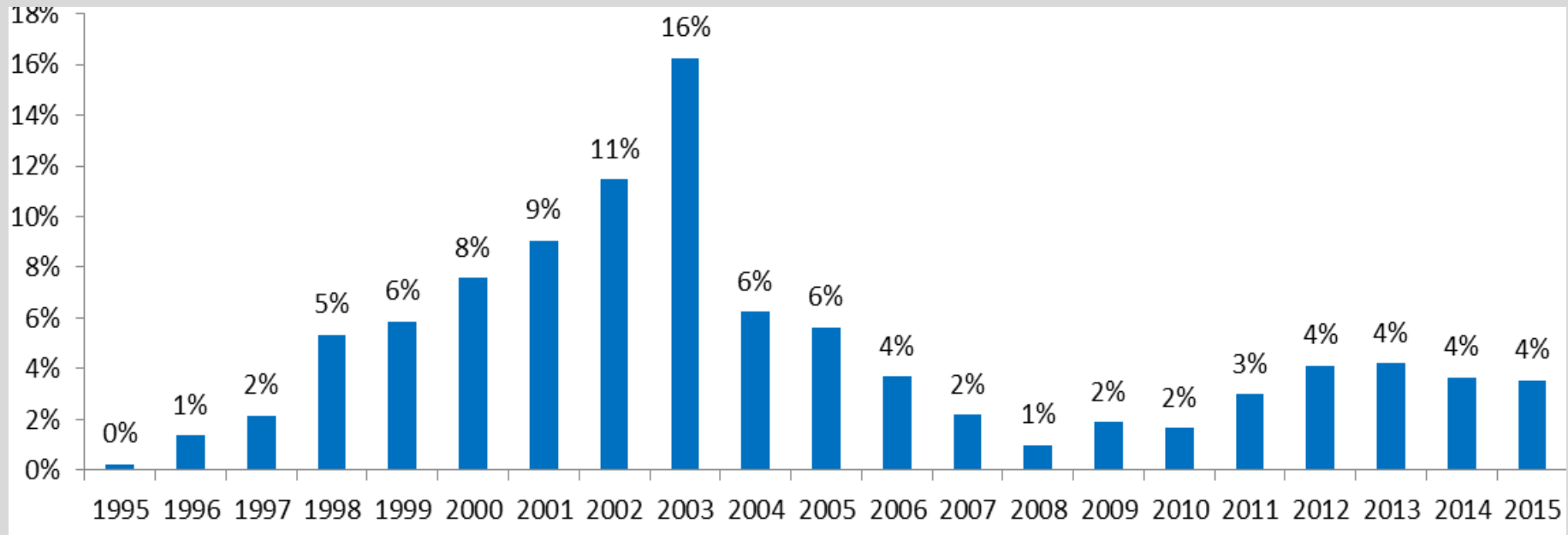
4,204 suppliers from 47 countries

65% low tech; 35% high tech

33,414 orders

4.3 Billion CHF of expenditure
(volume of orders)**

Volume of the orders by year - %



*Period: 1995 – 2015; Orders > 10,000 CHF (about 8,500 Euro)

** About 3 Billion EUR.

SCIENCE VS FACEBOOK

LHC generates scientific data from one billion particle collisions per second

300 Pb
2014



Content in the **Facebook** data warehouse
(1PB = 10^{15})

CERN with:

- 10,000 servers
- 174,000 physical processor cores
 - 350,000 logical cores

=
Pb *flow per day*, equivalent of 210,000 DVDs

LHC's data taking in past years:

- 150 Pb on disks, Meyrin
- 250 Pb on tape
- 100 Pb, Budapest

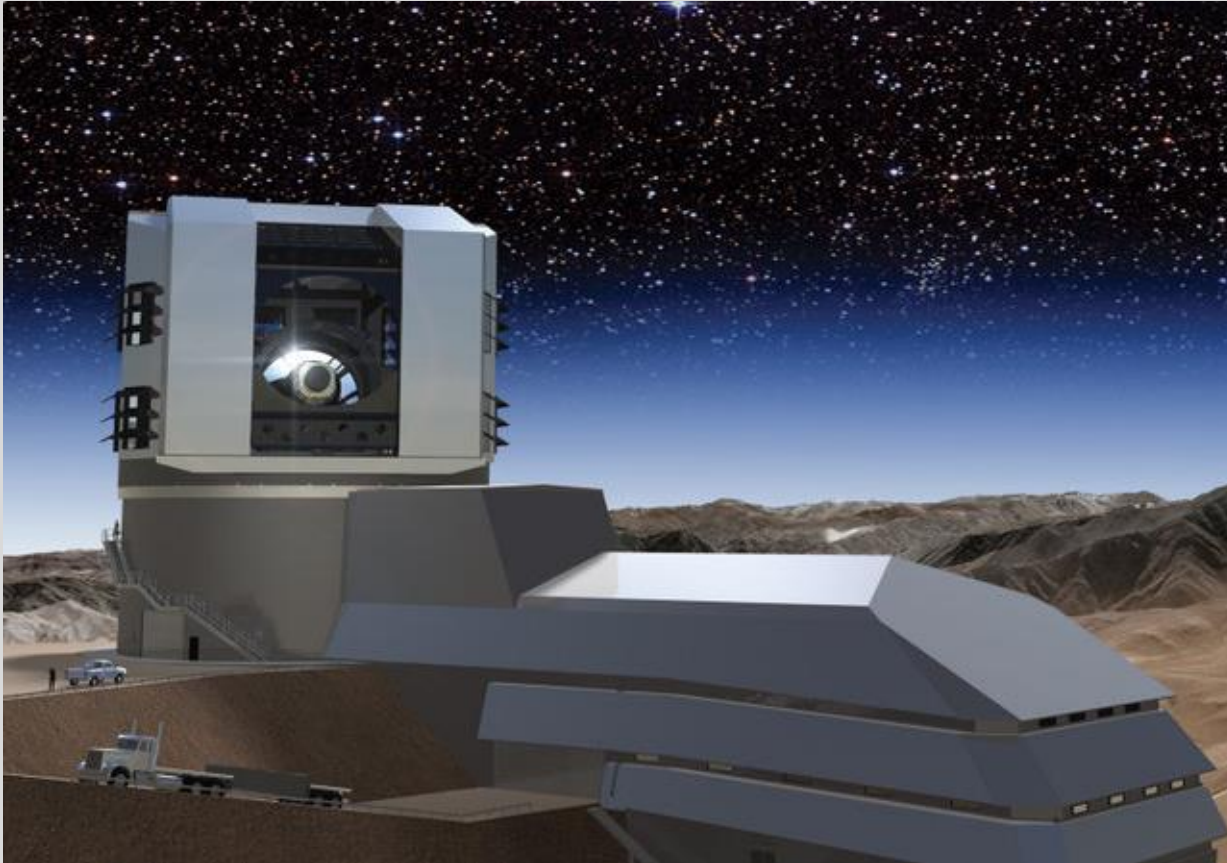


The WLCG distributes 30-50 Pb of data per year to the scientific community of particle physicists for analysis, through 170 computing centers, in 42 countries

<https://code.facebook.com/posts/229861827208629/scaling-the-facebook-data-warehouse-to-300-pb/>, accessed on May 7, 2018.

<https://home.cern/about/computing>, accessed on May 7, 2018.

THE LARGE SYNOPTIC SURVEY TELESCOPE (Cile)



Courtesy of @NPR

Sky observations in the mid-2020s: 200 PB of data

Challenge: software to process and store more than 30 TB (TB = 10^{12}) of data each night

Every night:

- 27-ft (8.4-m) mirror
- 3200 megapixel camera
- Each image the size of 40 full moons
- 37 billion stars and galaxies
- 10 year survey of the sky
- 10 million alerts
- 1000 pairs of exposures
- 15 terabytes of data

PRODUCT SPIN OFFS

- Since 1976, NASA's Spinoff publication has featured nearly 2,000 NASA technologies-turned-commercial-products. There's more space in your life than you think!
- spinoff.nasa.gov



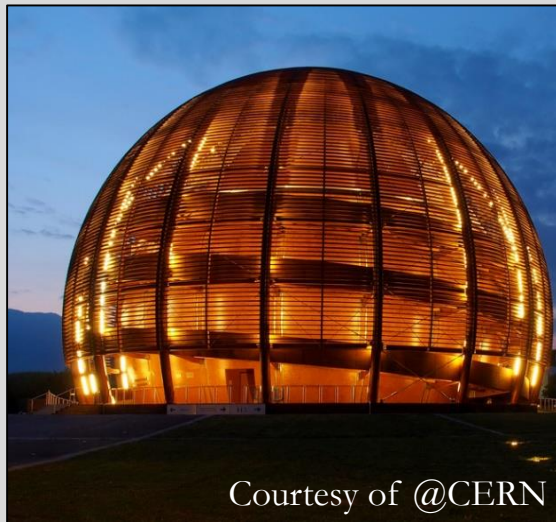
THE VALUE OF FUN

THE ECONOMICS OF 'WOW' AND CITIZEN SCIENCE



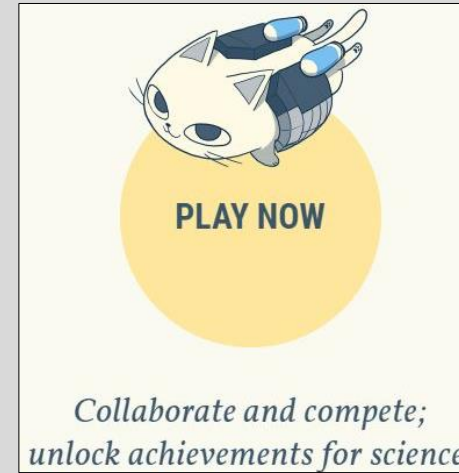
Courtesy of @NASA

- **The NASA Kennedy Space Center (KSC):**
- More than 1.5 million visitors per year
- 2015: 11 million followers on Facebook
- February 2018: NASA Facebook had 20,911,149 “likes” and 20,937,006 followers



Courtesy of @CERN

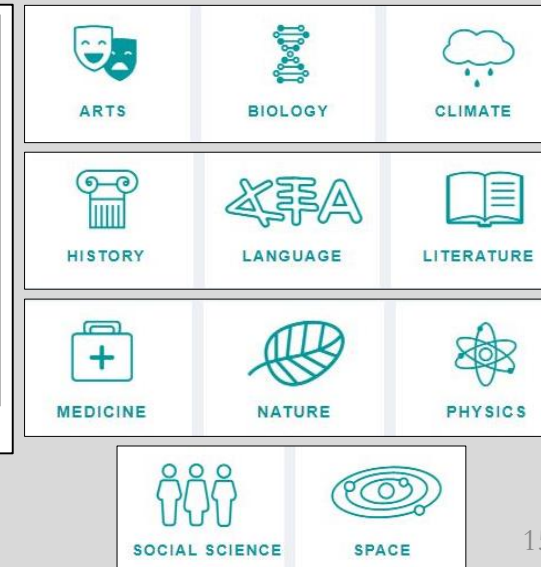
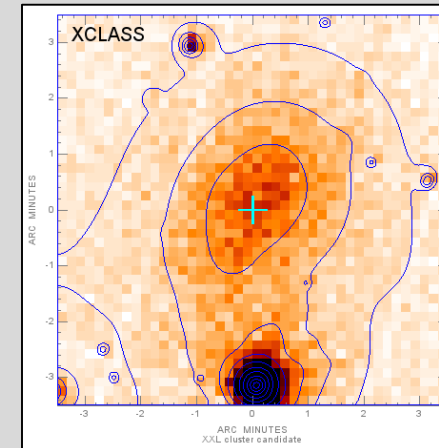
- **Public cultural value of CERN (1993-2038):**
- 5,1 mln CERN visitors
- 775 mln visitors to the sites
- 1,6 mln visitors to CERN’s exhibitions
- 29,3 mln of social media Users



- **EyeWire:** online game
- Supported by grants from the NIH
- Players are required to construct a 3D neuron map, starting from the retina of a mouse
- 250,000 players from more than 145 countries have signed up

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

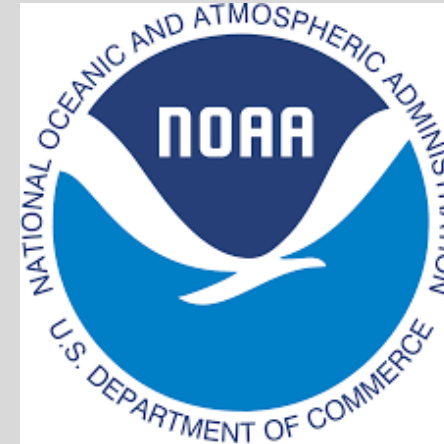
The Hunt for Galaxy Clusters Talk: Explore the depths of the Universe with Galaxy clusters



BENEFITS TO CITIZENS

CONTINGENT VALUATION (CV) - EXPERIMENT

- Since earlier '90s the willingness-to-pay (WTP) has been used to value public goods
- Contingent Valuation (CV) is a statistical technique used to elicit the WTP by directly asking people how much they would pay for a specific public good
- Thousands of studies worldwide have used CV for eliciting the WTP for:
 - environmental goods (e.g. ecosystems, forests, and endangered species)
 - cultural goods (museums, theatres, monuments, and cultural heritage sites)

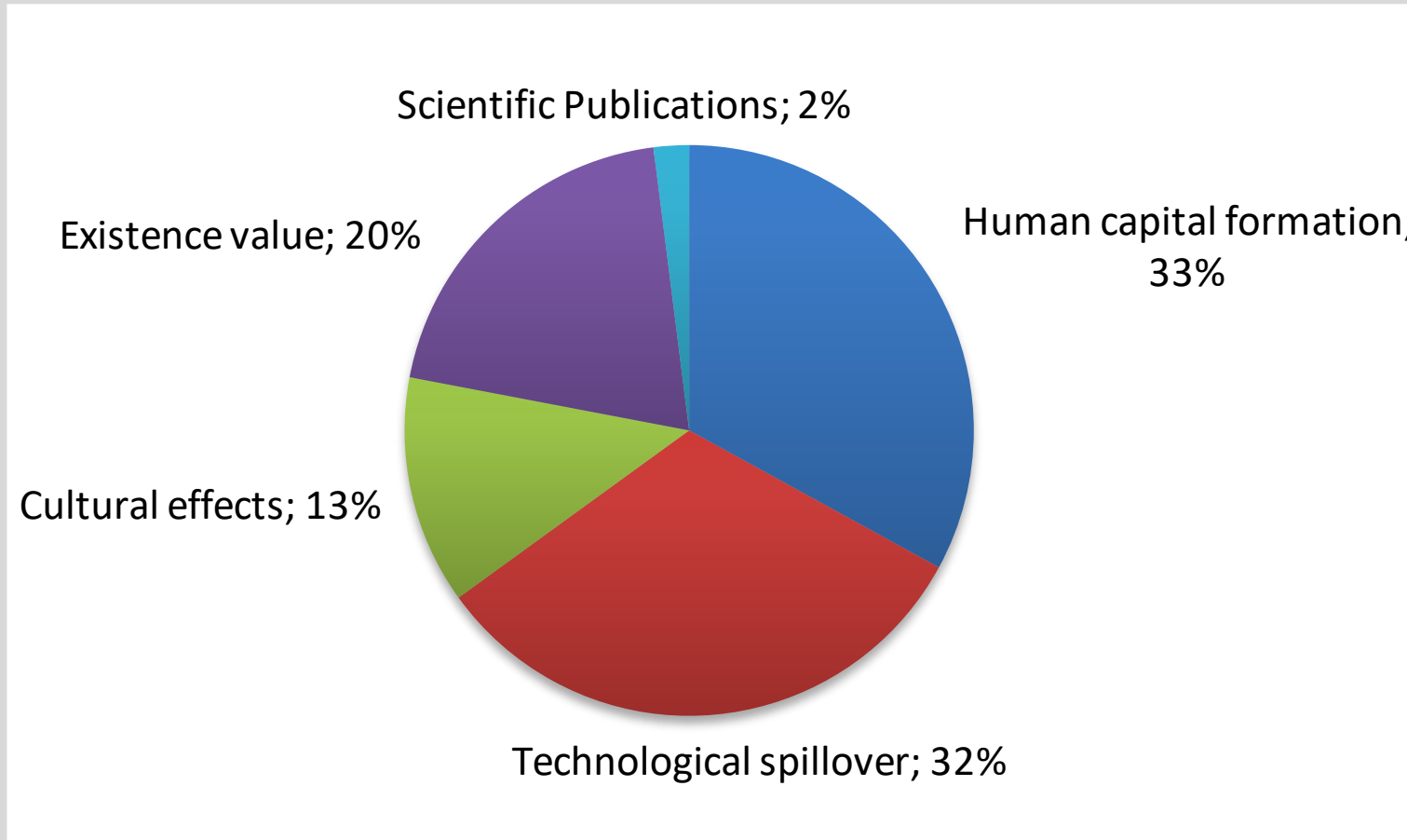


Report of the
NOAA Panel
on CV by
Arrow et al
(1993)



Contemporary
Guidance for
Stated
Preferences
Studies by
Johnston et al
(2017)

DISTRIBUTION OF BENEFITS



FURTHER QUESTION: RIS AS A PUBLIC ENTERPRISES

- *Enterprises*: efficient combinations of capital, labor, and knowledge, with budgetary autonomy and managerial discretion, to produce knowledge
- *Public* in two perspectives: because they are funded by governments and because most of the science they produce is a public good
- Perhaps the RI paradigm points to a possible new avenue in the governance of **knowledge-based organizations** beyond science, based on collective intelligence and intrinsic motivation, with implications also for **mission-oriented innovation policies** in such fields as climate change, sustainable energy and transport, digital society, demographic transition

CONCLUSIONS

- **RI as a new paradigm of production of science**
- Publication factories: diminishing value of co-signing an empirical paper against increasing role of recognition of individual contribution to a project. “Publish or perish” versus “**Teaming or perish**”. Economies of scale force universities to create academic **coalitions around RIs** and divest major internal facilities: this redefines universities
- Technological hubs: KT important but more incidental than deliberate, **large unexploited potential**
- Big Data: interplay between science and internet/knowledge based companies creates a **potential contradiction between open science and private appropriation of information**
- Tracking innovation: unsystematic (except perhaps at NASA) and need to develop new empirical strategies (**beyond patents**)
- The value of fun: science as a cultural good, surprisingly high-impact
- Public good value: crucial issue the estimation of **citizens/taxpayers WTP**
- Further question: knowledge based public enterprises for new public missions

Thank you
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Courtesy of @CERN

“Investing in Science” MIT Press

launch event of the book

Tuesday 3 December 2019, 5.00 p.m – 6.30 p.m

CERN, Globe of Science and Innovation

Live webcast available, you are welcome:

<https://webcast.web.cern.ch/event/i863086>