OPEN UNIVERSE: A SOCIAL COST-BENEFIT ANALYSIS PERSPECTIVE

Massimo Florio

Università degli Studi di Milano

United Nations/Italy Workshop on The Open Universe Initiative
Vienna 21 November 2017

OUTLINE

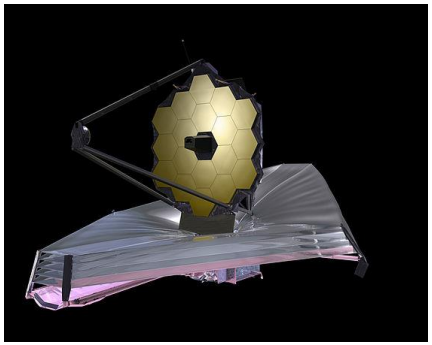
- Open Universe as a research infrastructure
- Cost Benefit Analysis of RI
- The social benefits of Open Science
- Estimation of benefits to scientists
- Benefits to user-citizens
- Benefits to non-user-citizens
- Conclusions

WHAT A RESEARCH INFRASTRUCTURE IS?

…"They include: major scientific equipment (or sets of instruments); **knowledge-based resources** such as collections, archives, or scientific data; e-infrastructures, such as data and computing systems and communication networks…".

Source: European Union Horizon 2020 Work Programme

SKA

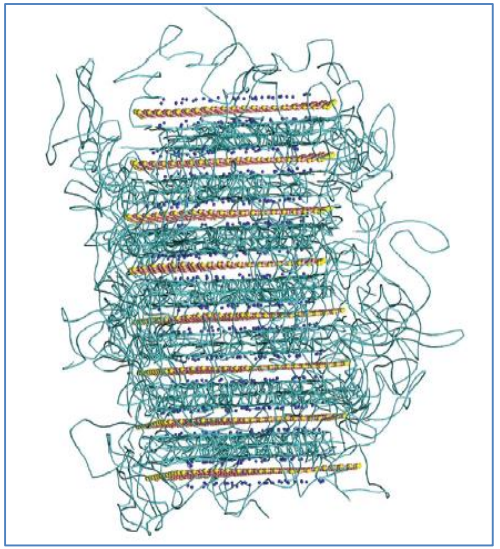


James Webb Space Telescope

OPEN UNVERSE AS A RESEARCH INFRASTRUCTURE?

…"Such infrastructures may be **'single-sited'**, **'virtual'** **or** **'distributed'**… By offering high quality research services to users from different countries, by attracting young people to science and by networking facilities, research infrastructures help to structure the scientific community and play a key role in the construction of an efficient research and innovation environment.".

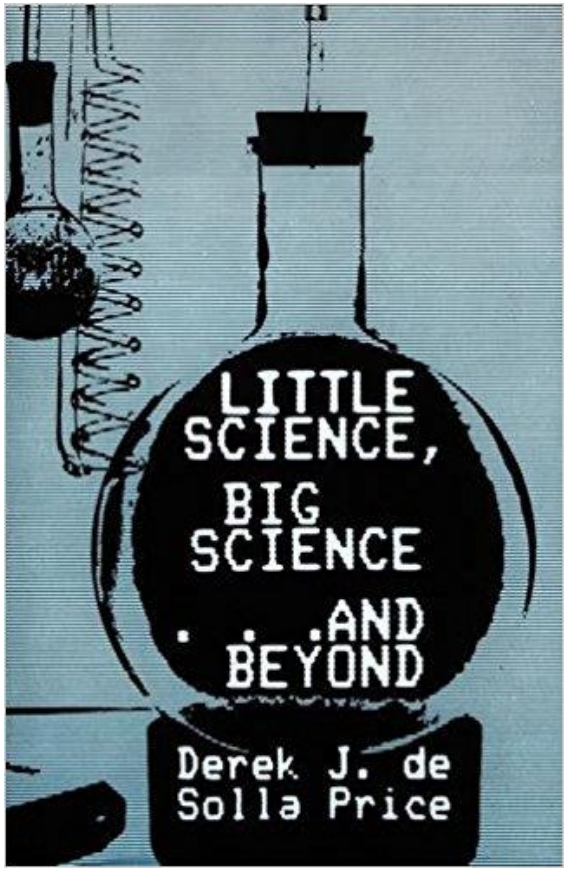
Source: European Union Horizon 2020 Work Programme



PRACE the virtual laboratory

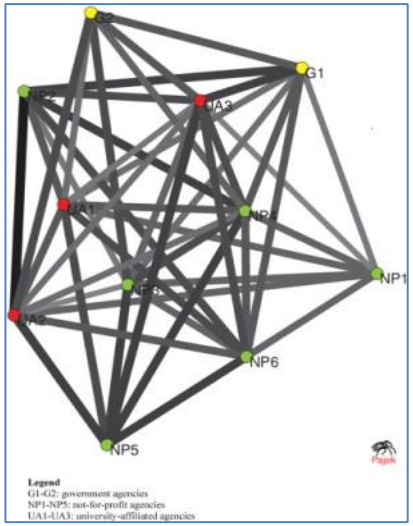
RI AS A NEW PARADIGM

- **New research organizational models** have evolved gradually away from the top-down Big Science paradigm.
- Acknowledgement by the scientific communities of the need of creating **common platforms**, shared by a plurality of teams.
- This is the **essence of the RI concept**, and has far-reaching consequences in terms of funding, ownership, governance, organization, stakeholders involvement and openness to outsiders, including the laypeople.



THE INGREDIENTS OF THE NEW RI PARADIGM

- **Flexible accessibility to multiple users**
- **Shared management**
- **Human capital incubator**
- **Technological hub**
- **Public involvement**
- **Large CAPEX and OPEX with multiple funders**
- **Generation of an unprecedented amount of digital information**
- Under this angle contemporary telescopes, probes in outer space, etc. are similar to particle accelerators and genomics platforms and other bioscience databases



THE OPEN SCIENCE MODEL

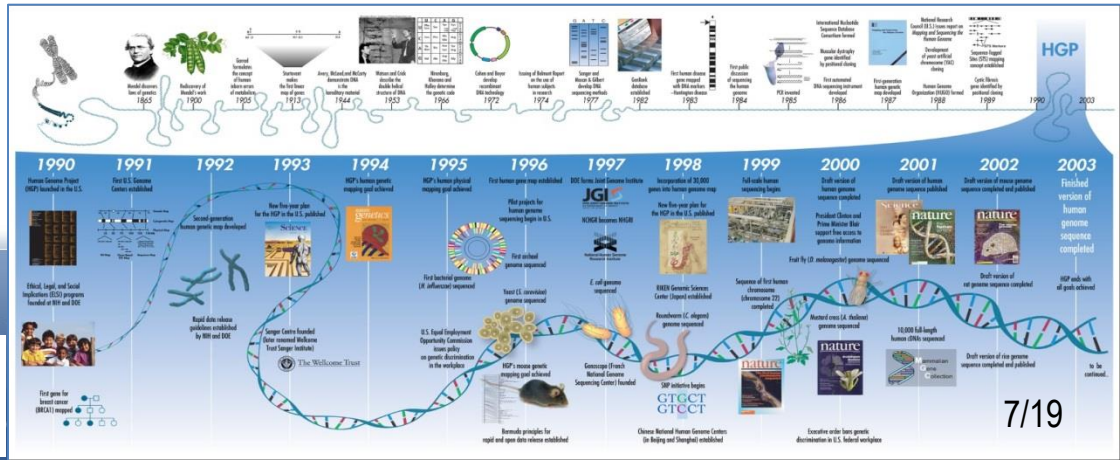
What is the social value of open data in this context ?

Three effects:

- **On researchers**
- **On citizen-scientists**
- **A public good value**

The key feature and potential benefits of the Open Universe initiative:

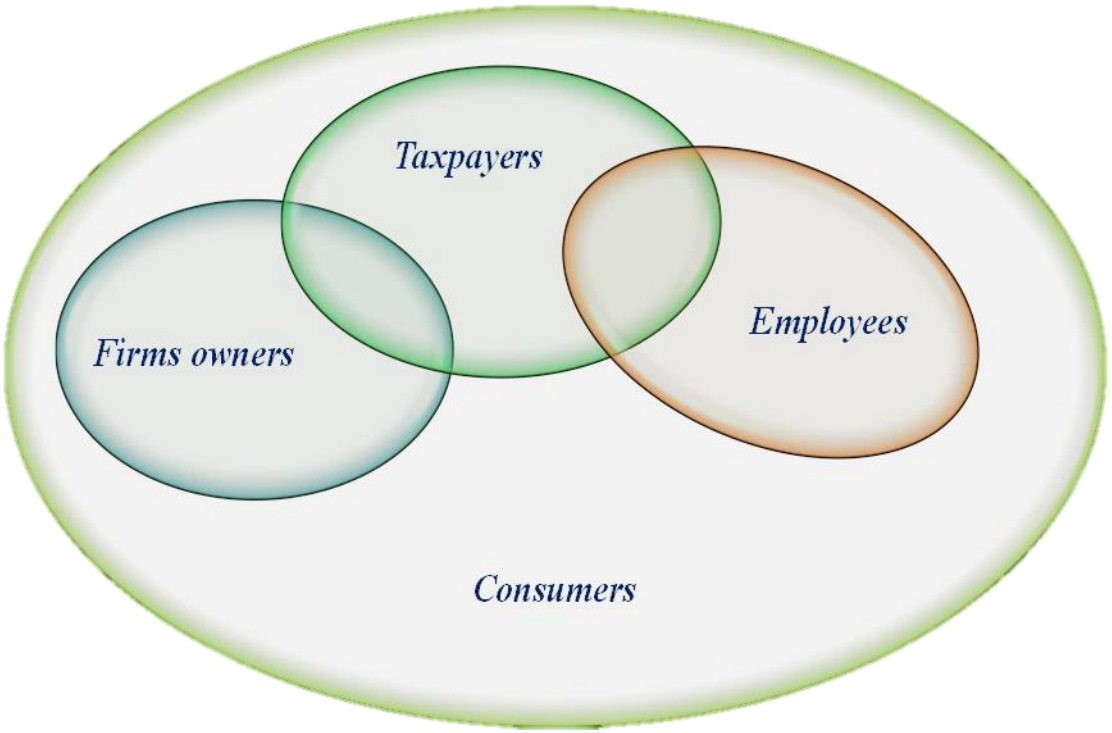
- Expanded data availability to the global community of space science. This is similar to what has been achieved with the Human Genome Project and with other large-scale bio-databanks
- Engagement of citizen-scientists. This is similar to the zoo-universe and other platforms but on a much larger scale
- Public good value for non-users



Human Genome Project [1990-2003]
Credit : Darryl Leja NHGRI

A CBA MODEL FOR RIS: BENEFITS (1)

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



- **Drèze, J. and Stern N. (1990)**
- **Johansson, P-O and Kriström, B. (2015)**

- **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.

A CBA MODEL FOR RI: BENEFITS (2)

Use Benefits B_u

FIRMS

Technological externalities (T_t)

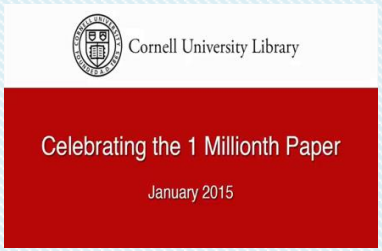
EMPLOYEES: early career researchers

Human Capital Formation (H_t)

CONSUMERS

Social benefits to consumers of services (A_t)

SCIENTISTS



Knowledge output (S_t)

VISITORS

Cultural effects (C_t)

CONSUMERS

Non Use Benefits B_n

?

Quasi option value (QOV)

TAXPAYERS

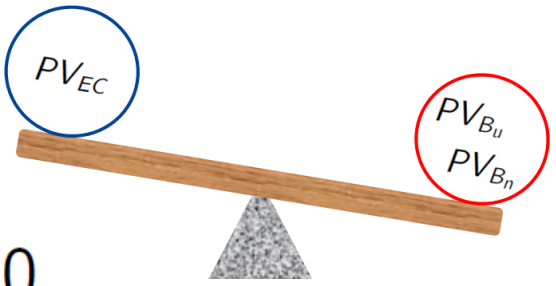
Existence value (EXV)

SOCIAL CBA OF RI - METHODOLOGY IN A NUTSHELL

$$\mathbb{E}\left(NPV_{RI}\right) = \mathbb{E}\left[\underbrace{\left(PV_{B_u} - PV_{EC}\right)}_{NPV_u} + PV_{B_n}\right]$$

- NPV_{RI}: Net Present Value (NPV) of a RI
- $NPV_u = PV_{B_u} - PV_{EC}$: benefits for users of the R
- $PV_{B_n} \approx EVX$: benefits for non–users $\approx$ "public good value" of scientific discovery
- PV_{EC}: economic costs (i.e. operating, inv. costs and externalities, if any)
- PV_{B_u}: benefits of stakeholders

$\Longrightarrow$ RI passes CBA if:



$$\mathbb{E}\left(NPV_{RI}\right) > 0$$

CULTURAL IMPACT: ILLUSTRATIVE EXAMPLE

- 1,5 million: yearly visitors at Kennedy Space Center
- 50 years: time horizon of KSC
- 75 million: total number of visitors
- 100 USD : WTP per visitor (including travel cost)

Benefit (undiscounted) = USD 7.5×10^9

+

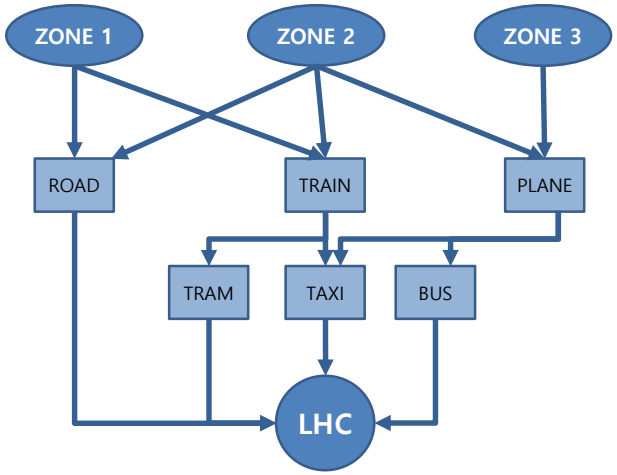
WTP of millions of virtual visitors through the web, media, etc

CULTURAL EFFECTS OF LHC

Source: Florio, Forte e Sirtori 2017 (in Technological forecasting and social change)

TRAVEL ZONES CONSIDERED

VALUATION THROUGH THE TRAVEL COST METHOD

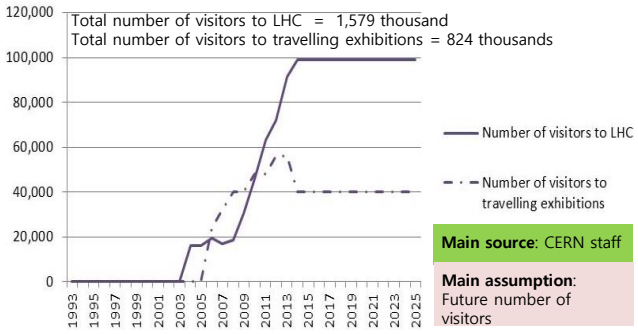


Main assumption:
- % of visitors by mode of transport
- Travel cost by zone

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

BENEFITS TO PERSONAL VISITORS: QUANTIFICATION OF VISITORS



Main source: CERN staff

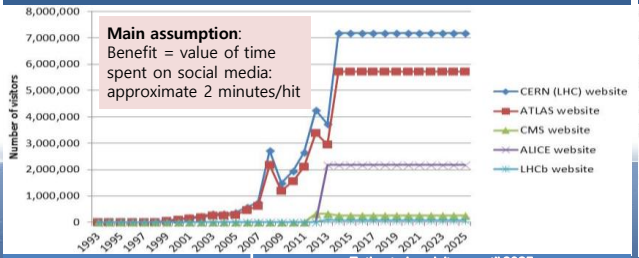
Main assumption: Future number of visitors

MASS MEDIA BENEFITS: NEWS BY MEDIA CHART

Color	Name	Value	Pct.
	Online, news and business	2301	34.69 %
	Blog, consumer	1132	17.07 %
	Newspaper	780	11.76 %
	Online, consumer	599	9.03 %
	Online, trade/industry	392	5.91 %
	Television program	130	1.96 %
	Wire service	93	1.40 %
	Magazine, trade/industry	82	1.24 %
	Newspaper, community	63	0.95 %
	Magazine, consumer	56	0.84 %
	Publication, college/alumni	30	0.45 %
	Cable/satellite - network/station	25	0.38 %
	Online, technical/scientificacademic	23	0.35 %
	Television station	23	0.35 %
	Magazine, news and business	22	0.33 %
	Radio station	18	0.27 %
	Magazine, technical/scientificacademic	8	0.12 %
	News/Release Distribution Service	5	0.08 %
	Newspaper publisher	4	0.06 %
	Television network	4	0.06 %
	Television program, national	2	0.03 %
	Blog, news and business	1	0.02 %
	Radio program	1	0.02 %
	Syndicate	1	0.02 %
	(None)	648	9.77 %
	(International)	190	2.86 %

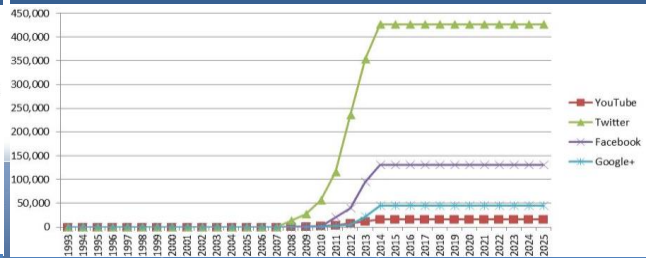
01/09/2008 to 18/09/2008

BENEFIT FOR WEBSITE VISITORS



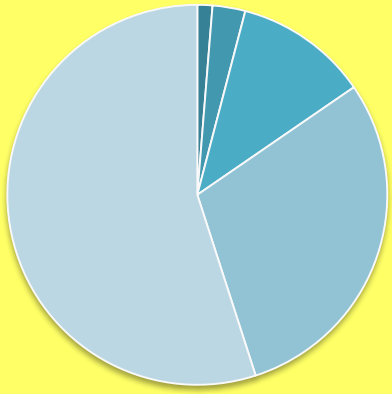
	Estimated n. visitors until 2025
CERN (LHC) website	211,924,673
ATLAS website	168,746,259
CMS website	7,190,918
ALICE website	56,514,575
LHCb website	1,966,268
TOTAL	446,342,693

BENEFIT FOR SOCIAL MEDIA USERS



	Estimated n. Users until 2025	Average duration. Minutes/month
Youtube	436,350	0.5
Twitter	11,825,400	0.5
Facebook	3,460,698	0.5
Google+	1,139,964	0.5
TOTAL	16,862,412	

OUR PRELIMINARY RESULTS



- social media users
- volunteer computing
- website visitors
- mass media on general public
- personal visitors

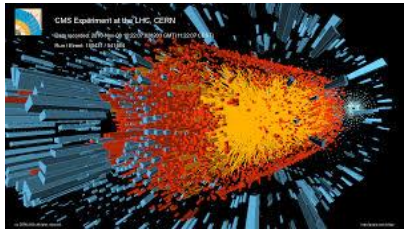
Total present value of cultural effects 2,099.8 million EUR

- To a certain extent, **these externalities can be measured**, valued, and then entered in an RI's social cost-benefit analysis. There are two main approaches.
- One is the **avoided cost** by using open data and open source software.

Users create by themselves information and tools which they have accessed free of charge. Such avoided costs are a practical way to estimate the willingness to pay (WTP) and is based ultimately on the opportunity cost of time of scientists, professionals, and laypeople in communities outside the RIs.

EXAMPLES

- In the cost benefit analysis of the LHC the value of two open access software – Root and Geant4 – was found by Florio, Forte and Sirtori (2016) at 2.8 billion euro out of 13.5 billion LHC cost to 2025
- a CBA of the European Bioinformatics institute after interviewing more than 4500 users has found that:



"**Access (use) value:** The most direct measure of the value is the time and therefore costs users spend accessing EMBL-EBI data and services - an estimated £270 million during the year to May 2015. " .

The second approach is to search explicitly for the WTP of certain users, either through **market data**, or following a **stated preference approach**, which is well developed in environmental economics since more than 20 years but not yet in the evaluation of science projects.

Examples

In the CBA of the European Bioinformatics Institute " measuring the value users place on a freely provided service... is an estimated £322 million during the year to May 2015. " This was again based on the survey of more than 4500 users.

" This is compared with ...." £47 million annual operational expenditure, with a minimum direct value to users that is equivalent to around 6 times the direct operational cost. " Beagrie N and Houghton J. , 2016)

They also report wider effects (much more uncertain)

Efficiency impacts: Users reported that EMBL-EBI data and services made their research significantly more efficient. This benefit to users and their funders is estimated, at a minimum, to be worth £1 billion per annum worldwide - equivalent to more than 20 times the direct operational cost.

Return on Investment in R&D: during the last year the use of EMBL-EBI services contributed to the wider realization of future research impacts conservatively estimated to be worth some £920 million annually, or £6.9 billion over 30 years in net present value.

Moreover, there may be a **non-use value of Open Universe as a public good**.

- In **environmental economics** it has been discovered that citizens have preferences for **the pure existence of some goods**, even if they do not plan to use them (e.g. they do not plan to personally access the Human Genome Project database).
- The existence, or intrinsic value of a public good can be revealed by **contingent valuation experiments**. Their objective is to discover the **willingness to pay** through specially designed surveys of citizens.
- **Methodological guidelines** have been provided by a NOAA high level panel of economists Chaired by the Nobel Laureate Kennewth Arrow (1993)

- Florio, Forte and Sirtori (2016) suggest that the perceived intrinsic value of the LHC science to citizens is 3.2 billion euro.

More recently for review and methods see Johnston et al 2017

Conclusions

The Open Universe initiative has certain costs. These need to be predicted with an appropriate scenario analysis. Against these costs there may be three types of measurable direct social benefits (without any further benefits from discoveries)

A) Benefits to researchers. These can be quantitatively estimated with two complementary methods: (1) ***(average unit value of the time saved)*** *x* ***(frequency of access by scientists)*** and/or

B) ***(marginal willingness to pay for access) x (frequency of access)***

C) Benefits to user-citizens. These can be estimated by **WTP surveys** of samples of citizen-scientists

D) Benefits to non-users-citizens. These can be estimated by contingent valuation experiments on the WTP for 'Open Universe' as a public good with representative samples of the population, in compliance with international guidelines .

Small-scale pilot experiments are needed for pre-testing: a new field.

SOME BIBLIOGRAPHY (1)

- **Special Issue on The social impact of Research Infrastructures at the frontiers of science and technology** (2016) Guest editors: Chiara Del Bo, Massimo Florio and Stefano Forte

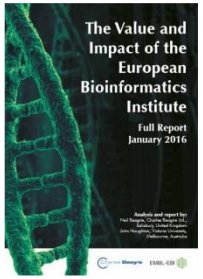
Csil
CENTRE FOR INDUSTRIAL STUDIES

- 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

Cornell University Library
arXiv.org

- 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

SOME BIBLIOGRAPHY (2)



- Beagrie N, Houghton J.(2016) **The value and impact of the European Bioinformatics Institute**, EMBL-EBI

- Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., Hanneman, W.M., Hanley, N., Ryan, M., Scarpa, R., & Tourangeau, R., and Vossler, C.A. (2017) **'Contemporary guidance for stated preference studies',** Journal of the Association of Environmental and Resource Economists, 4(2), 319-405.

- Johansson, P-O and Kriström, B. (2015). **Cost-Benefit Analysis for Project Appraisal**, Cambridge: Cambridge University Press.

THANK YOU

massimo.florio@unimi.it