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Social benefits and costs of large scale research infrastructures

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ABSTRACT

This paper explores some of the methodological issues involved in a cost–benefit analysis framework for large scale capital-intensive research infrastructures. We propose a conceptual model based on the estimation of quantities and shadow prices of cost aggregates, and of six main categories of economic benefits: technological spillovers, human capital formation, knowledge outputs, cultural effects, services to third parties including consumers, and a public good, the pure value of discovery. We justify the reasons why these benefits of research infrastructures should be often expected to be the core ones in ex-ante project evaluation. Other benefits may be considered as well, but often by qualitative methods only. Empirical approaches are suggested for further applied research.

1. Introduction

Research, development and innovation are increasingly at the centre of political agendas as tools to stimulate economic growth, with the intellectual support of a new understanding by economists of the endogenous drivers of social change.[1] In the European Union (EU), the 'Europe 2020'[2] strategy includes the Innovation Union flagship initiative, aimed at transforming Europe into a world-class science performer, by establishing a common European Research Area and completing or launching the construction of priority European research infrastructures (RIs). Other countries, including China, are planning large-scale scientific ventures for the next decades.[3] In this paper we focus on the evaluation of large-scale research infrastructures. Governments are not always able or willing to foot the bill of Big Science.[4] In the early Nineties, the Superconducting Super Collider, an 87 km circumference particle accelerator, was to be built in Texas with an initial budget of USD 4.4 billion. After having already spent USD 2 billion and dug 23.5 km of underground tunnel and 17 pits, the cost for the project completion rapidly surged to USD 11 billion and the project was eventually abandoned by the US Congress (Baggott, 2012; Giudice, 2010; Maiani and Bassoli, 2012).

The increasing costs of RIs call for a critical evaluation of their social impact (Broad, 1990). Typically, the decision of funding highly expensive RIs is advocated by a coalition of scientists, often supported by peer reviews or other expert opinions, to convince the policy makers about the case for a new project. This process can be described as a lobbying approach to science policy. Lobbying is, historically, a feature of any major infrastructure decision process, e.g. in transport, energy, and water (see Cassis et al., 2015) and cost–benefit analysis (CBA) has evolved since its origins at the French École National des Ponts et Chaussées (Dupuit, 1844) as a way to counterbalance it. CBA consists in assessing whether benefits accrued from a project are in excess of its social costs, thereby showing if the project represents a net benefit to the whole society. The key strength of this approach is that it produces information of the project's net contribution to the society, summarized into simple indicators, such as the economic net present value (NPV).

Is it possible to adapt CBA methods in the context of Big Science? This is our research question.

Whatever the difficulty in estimating the social cost of any investment, because of lack of data or specific conceptual issues, particularly when externalities are considered,[5] a standard CBA theory for the estimation of their value to society is well established (see e.g. Drèze and Stern, 1987; Johansson, 1991; Johansson and Kriström, 2015; Pearce et al., 2006; Florio, 2014). There is a long worldwide experience in the CBA of traditional infrastructures, and more recently in environmental services, health, education and culture. This paper explores some of the methodological issues involved when evaluating RIs through the

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[1] See, for example, Griliches (1980); Adams (1990), Romer (1990), and Barro and Sala-i-Martin (2003).
[2] European Commission (2010).
[3] See for example the proposed Circular Electron Positron Collider (see cepc.ihep.ac.cn).
[4] The term 'Big Science' was coined fifty years ago to describe the large-scale character and complexity of modern science, in contrast with the formerly predominant 'Little Science' (de Solla Price, 1963; Weinberg, 1967).

[5] Projects aimed at tackling climate change are an extreme example. See the Stern Review (HM Treasury, 2006).

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CBA framework, and suggests that such a framework can be designed and applied empirically, with due caution given its experimental nature. However, in this paper we do not deal specifically with the issue of uncertainty, a crucial one for forecasting the social impact of RIs, because of the stochastic nature of many variables involved in the computation. This issue will be treated in a different paper (Florio et al., 2015b). In principle, all the variables included in the model that we are going to present should be considered at their expected value arising from an underlying probability distribution, according to the risk analysis framework (see Florio, 2014, Chapter 8). Thus we shall not repeat each time that in fact we are not dealing with a punctual forecast, but with a range of values for which the mean one is a convenient reference point under risk neutrality.

The structure of the paper is as follows: in Section 2, after defining the RI, we outline a conceptual CBA model and we propose and justify a taxonomy of benefits. Section 3 examines the social demand for RI and the social value of six main types of benefits. We discuss knowledge outputs, technological externalities, human capital development, wider cultural effects, services to third parties, and a non-use benefit: the pure value of discovery. For each of these six effects we mention empirical approaches for estimation of marginal social values. Section 4 concludes by putting together the cost and the benefit sides of the discussion, mentioning risk and the need for empirical research.

2. Conceptual framework

While CBA started in transport and water infrastructure, it then was applied in energy, telecommunications and other services. In the Eighties it was often maintained that investment in sectors such as education or health could not be evaluated by CBA techniques (see e.g. Baum and Tolbert, 1985), while this is now an accepted practice (see e.g. Viscusi and Aldy, 2003; the World Health Organization, 2006, on cultural projects in the UK see DCMS — Department for Culture, Media and Sport, 2010). Indeed there are some ingredients of RIs that are peculiar to them, but several are shared with other categories of infrastructures.

A *first* critical ingredient of any infrastructure is high capital intensity at an early stage of the project cycle (Gramlich, 1994). This is particularly true in Big Science, which is performed using some of the most expensive machines ever built. For the International Space Station, total costs are reported by the European Space Agency to be around USD 100 billion over a 30-year period.[6] Fixed investment costs of smaller RIs[7] also tend often to be larger that operating costs.[8] In contrast, we would exclude from the definition of RIs social surveys, since the service they provide is more labour, rather than capital, intensive, but see ESFRI — European Strategy Forum on Research Infrastructures (2011) which considers as RIs electronic surveys, such as the European Social Survey.[9]

A *second* ingredient is the long time horizon involved in both the cost side and the benefit side. For example CERN accelerators built in the late Fifties (Proton Synchrotron) and in the Seventies (Super Proton Synchrotron) are still used as injectors of proton beams in the Large Hadron Collider (LHC). The time horizon is however not necessary longer, and is often shorter than traditional infrastructures, such as e.g. roads, railways or dams. The time span of benefits is also long, as it is discussed below: decades if not centuries.

Third, 'standard' economic infrastructures are often associated with externalities and spillover effects: part of the economic benefits of an infrastructure is usually not appropriated by its owner, and we shall show that this is a core feature of RIs as well.

Fourth, there is no explicit market for all the services of the RI and very limited competition (Irvine and Martin, 1984). However, sometimes in Big Science the same research question could be answered in principle by more than one competing RI[10] (see Baggott, 2012). This adds to the interest of evaluating the relative costs and benefits of competing projects.

We argue that 'research' relates to all those activities which elaborate data and information for creating new knowledge. According to this criterion, RIs include both facilities for *pure* and *applied* research. University laboratories generally fall into this category.[11] Most of RIs are single-sited,[12] but there are also examples of geographically distributed facilities, such as grid computing systems or atmospheric measurement stations located in different areas and recording data which are then centrally studied.[13] In such cases there may be network externalities to be considered in the project's impact assessment.[14] Some RIs are mobile, as oceanographic vessels and satellites.

To sum up, for the purpose of the CBA conceptual framework suggested in this paper we understand RIs as (a) high-capital intensity, (b) long-lasting facilities or networks (c) typically operating in 'monopoly' or 'oligopoly' conditions, and affected by externalities (d) whose objective is to produce social benefits through the generation of new knowledge, either pure or applied.

The literature on the social benefits stemming from research is huge, and in some earlier RI literature[15] many 'positive outcomes' are listed. We are not going, however, to review here such literature on the social impact of technology progress, innovation and science, a stream that has been blooming over decades, with a variety of approaches, going from adaptation of macroeconomic tools, such as aggregate production functions augmented with R&D expenditures and input–output models, micro-econometrics applied to firm-level data, patent data, business surveys, and qualitative approaches. For recent surveys or critical reviews see for example OECD (2014b), Martin and Tang (2007), Technopolis (2011), European Space Agency (2012), Browny and Rosenberg (2010) and the reviews by Del Bo (2014) and Gomez (2015). While we take advantage of the deeper understanding of the social impact of research and experimental development thanks to earlier literature, and some of it will be cited later in the discussion of specific social benefits of RIs, we focus here exclusively on its relevance for a CBA framework.

We propose to consider a simple CBA model for RIs consistent with applied welfare economics principles (Florio, 2014). Before introducing the model we discuss qualitatively the identification of beneficiaries of research infrastructures, as ultimately a CBA aims at tracing the social impact of a change on individual economic agents or their aggregates. Then, in the rest of the paper, we discuss each of the model components.

[6] http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/How_much_does_it_cost.

[7] Examples include the Italian Laboratory for the Study of the Effects of the Radiation on Material for Space, the Finnish Centre of Excellence in Environmental Health Risk Analysis or the Hungarian Cyclotron of Atomki that provides accelerated particles that can be used for nuclear physics studies and for radioactive isotope production for application purposes.

[8] http://www.riportal.eu/public/index.cfm?fuseaction=ri.search.

[9] The European Social Survey is a network established to develop, store and study long time series of data used to monitor and interpret changes in European social attitudes and behaviour patterns.

[10] A comparative assessment of the advantages and disadvantages of the CERN Large Electron-Positron (LEP) collider was conducted by Irvine and Martin (1984). This exercise shows that even very large and cutting-edge accelerators might have a number of rival projects.

[11] However, some university departments are not to be considered RI, but rather education facilities.

[12] Examples of single sited RIs include particle colliders, telescopes, research vessels and aircrafts, science parks, laser light facilities, microscopy facilities, research nuclear reactors, laboratories for zoology, botany, and some supercomputers.

[13] Other examples are seismographic stations and aquaculture and laboratory testing facilities.

[14] According to OECD (2014a) a distributed infrastructure is a network or multi-national association of geographically-separated organisational entities that jointly operate a set of independent research facilities, e.g. the European Very Large Baseline Interferometry Network that is a collaboration of the major radio astronomical institutes of Europe, Asia and Africa.

[15] See Salter and Martin (2000); Hallonsten et al. (2004); SQW Consulting (2008); Czech Ministry of Education, Youth and Sport and JASPERS (2009); Science and Technology Facilities Council (2010); COST Office (2010); JASPERS (2013); and Bach (2013).