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The rate of return to investment in R&D: The case of research infrastructures

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ABSTRACT

The return to R&D investment and activities has been the object of a vast literature, both from a theoretical and empirical perspective. The aim of this overview is to present a selection of contributions to underscore the main shared findings and highlight open issues, while also providing a preliminary analysis of the returns to R&D investment in large research infrastructures (RIs) in Europe. First, a common methodological framework is distilled from the macro-literature, examining the return to R&D in aggregate terms. Then, the evaluation in the context of specific projects, mainly in large RIs, is examined, followed by the explicit consideration of externalities and spillover effects of research activities. A novel empirical analysis of European RIs is also presented, based on a novel data set, to highlight trends and suggest new avenues for the evaluation of the rate of return to investments in research infrastructures, using both a cost effectiveness ratio and a bibliometric citation count as metrics to evaluate the return to R&D investment in these facilities. Directions for future research are sketched in the concluding section.

1. Introduction

Large R&D projects, such as research infrastructures (henceforth, RIs), require substantial capital investment, mostly financed by means of public funds. The injection of significant public resources to RIs in the European Union (EU) is motivated by the recognition of their positive contribution to expanding the scientific and technological knowledge frontier, by fostering scientific discovery and acting as incubators of innovative technologies.[1] The scope of potential benefits, beyond pure knowledge, accruing to both supplier and user industries of RIs, has indeed fostered an increase in EU funds aimed at supporting RIs. From a mere €30 million allocated within Framework Programme 2 (FP2) between 1987 and 1991, €1.85 billion were committed for RIs between 2007 and 2013 in the context of FP7, and the Horizon 2020[2] Programme's budget for RIs is of around €2.5 billions between 2014 and 2020.[3] Further, an EU-wide roadmap for RIs is being implemented under the supervision of the European Strategy Forum on Research Infrastructures (ESFRI), further suggesting the attention given to this specific form of research collaboration.

Given the importance attributed to RIs for the achievement of excellence in science, innovation, and technology and the amount of funds earmarked by the EU to promote and sustain them, a better understanding of their impact on the European economy is crucial. The aim of this paper is twofold. On the one hand, it offers a critical reading of previous literature on the evaluation of the rate of return to investment in research and development (R&D) to gauge the potential benefits of RIs. On the other, the paper provides an overview of the characteristics of existing RIs in the EU and presents two possible measures (a cost effectiveness ratio and a bibliometric citation count) that can be seen as rough proxies of the rate of return to (public) investment in RIs. The empirical results presented thus suggest the dimensions along which existing and future RI projects, in different fields of science, can be examined to evaluate the potential returns to these endeavors. The goal is to frame further research on new methods to evaluate the rate of return to investment in RIs within previous literature and methodologies, while taking advantage of the stylized facts and empirical evidence concerning existing facilities in the EU.

While each project is characterized by idiosyncratic characteristics, influenced by the type of research carried out and the subject matter, that in the end determine the rate of return to capital investments, some common features and trends can be highlighted. RIs in the various fields of

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[1] European Strategy Forum on Research Infrastructures (ESFRI) http://ec.europa.eu/research /infrastructures.

[2] In certain cases, RIs could also fall within the scope of cohesion policy, if they can concur to address the issues of reducing disparities among European territories and help achieve sustainable growth.

[3] Figures taken from the ESFRI website, see note 1 (retrieved online on October 2, 2014).

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science may differ, for example, in terms of duration, costs, type of collaboration and partners, and countries involved, thus making comparisons in terms of a rate of return to the investment rather difficult. However, several strands of economic literature have focused on both the methodological issues and the empirical analysis related to the definition and quantification of the rate of return to investment in R&D, both at an aggregate and at a project-specific level. Thus, analyzing previous literature may shed light on a reasonable numeric range for this variable and suggest a reliable methodology to analyze the impact of research investment in general, and RIs, on economic variables. Can a common framework for the evaluation and appraisal of the contribution of RIs to economic well-being and growth be identified? Can a set of stylized facts on the rate of return be distilled from the analysis of existing RIs in Europe? To this end, in what follows, a selection of previous literature on the subject is presented, mainly with the aim of identifying methodologies and best practices in the evaluation of the rate of return to capital investment in R&D, rather than presenting a systematic survey of this burgeoning literature.[4] This overview is complemented by an empirical evaluation, based on a new data set prepared for this paper, of the main characteristics of European RIs. An initial sketch of a methodology for evaluating the rate of return to investment in RIs (focusing on a cost-effectiveness measure and considering the impact of scientific publications produced within the RI) is also proposed based on data from existing facilities in the EU.

The paper is organized as follows. In Section 2, an overview of the main characteristics of RIs in the EU is presented. In Section 3, previous literature on the return to R&D is presented. First, macro-evidence, based on aggregate endogenous growth models and econometric studies is examined. Subsequently, a selection of single case studies is surveyed to analyze the methodological evolution in assessing the rates of return and overall impact of R&D activities, especially of RIs. Finally, spillover effects and externalities and implications for rate of return calculations are presented. In Section 4, an initial empirical analysis of the rate of return of existing RIs in the EU is presented. Finally, Section 5 discusses and concludes.

2. The rate of return of RIs in the EU: some stylized facts

In this section, by using a new data set on European RIs, Riportal,[5] evidence on the main characteristics of these facilities is discussed.

According to Florio and Sirtori (2014), RIs can be defined as

> "(…) high-capital intensity and long-lasting facilities and equipment, typically operating in oligopoly conditions, whose objective is to support economic development and produce social benefits through the generation of new knowledge and, often, other spillover effects." Florio and Sirtori (2014), p. 7.

The main characterizing features that emerge, apart for a long life span, are thus related, on the costs' side, to significant investment and operational costs, and on the benefits' side, to the creation of new knowledge and significant spillover effects.

Data from the Riportal website on RIs of pan-European interest provide initial information on the characteristics, by the different sectors, or fields of science, and a tentative evaluation of the rate of return associated with the major RIs in the EU. Data on single RIs, available on the website, have been collected, codified, and aggregated in a single database with information on country and sector, years since the start of the operations of the RI (age of the RI), investment and annual operational costs, employees (defined as permanent scientific/engineering staff operating the RI), annual users of the RI (distinguishing between internal and external users), and main publications produced within the activities of the RI. Quantitative and monetary data are provided in classes, so the average value for each class is considered in the following empirical analysis.

Table 1
Geographic distribution of RIs.

Country	Frequency	Percent	Country	Frequency	Percent
Austria	8	2%	Israel	3	1%
Belgium	12	4%	Italy	27	8%
Bulgaria	4	1%	Netherlands	15	4%
Cyprus	2	1%	Norway	9	3%
Czech Republic	4	1%	Other	13	4%
Denmark	5	1%	Poland	8	2%
Estonia	1	0%	Portugal	1	0%
Finland	21	6%	Romania	5	1%
France	74	22%	Spain	22	6%
Germany	53	16%	Sweden	13	4%
Greece	8	2%	Switzerland	4	1%
Hungary	6	2%	Turkey	2	1%
Iceland	1	0%	United Kingdom	17	5%
Ireland	1	0%	*Total*	*339*	*100%*

Source: author's elaboration on data from Riportal (www.riportal.eu).

After deleting RIs with missing or incomplete information, the sample is made up of 339 RIs in 27 European countries (see Table 1 for a breakdown).

Considering the spatial distribution of facilities in the EU (Table 1), France, Germany, and Italy host the highest number of RIs, accounting for, respectively, 22%, 16%, and 8% of the total.

Using the sectorial breakdown available on the Riportal website, RIs can be divided in the following fields of science (Table 2).

There is a predominance of facilities in the "hard" science fields, with 23%, 22%, and 21% of RIs, respectively, in material sciences, chemistry, and nanotechnologies; environmental, marine, and earth sciences; and physics and astronomy.

Following the definition of Florio and Sirtori (2014), and focusing on RI's salient and distinctive features, Table 3 presents information, by field, on the age of the RI, cumulated investment costs and annual operational costs (both in million €) of the RIs.

From column 1, Table 3, European RIs are shown to have an average age of 21 years, with a maximum of 28 years and a minimum of 12 in the fields of energy and information and communication technologies, mathematics, respectively. Investment costs (column 2, Table 3) are the highest in energy, followed with significantly lower figures, by material sciences, chemistry, and nanotechnologies, and physics and astronomy. Differences across fields are not so pronounced when considering the average annual operational costs (column 3, Table 3), although the previous ranking of the most costly RIs by sector is unvaried. Overall, the amounts invested to both build and operate RIs are significant and coherent with the definition of RIs presented at the beginning of the Section.

The average number of employees, i.e., permanent scientific/engineering staff operating the RI, is of 57, with wide variability across fields (column 1, Table 4).

While RIs in humanities and behavioral sciences have, on average, only 14 full-time permanent staff, more technical fields, as expected, need more specialized personnel to operate the RI. In material sciences, chemistry, and Nanotechnologies and in physics and astronomy, the average staff is of 68 and 69, respectively. The information on the labor force operating the RI is also the basis for an indicator of efficiency, computed as the ratio between the sum of investment and cumulated operational costs per employee. The lowest values are found in the fields of information and communication technologies, mathematics; life sciences; and environmental, marine, and earth sciences. The highest values are instead recorded in the fields of energy and humanities and behavioral sciences.[6] Similar conclusions can be obtained by distinguishing

[4] For a rather comprehensive review of empirical contributions, see Hall et al. (2009), and for a general overview on the economics of science, see Audretsch et al. (2002).

[5] http://www.riportal.eu/public/index.cfm?fuseaction=ri.search. This data set has been discontinued in 2013 and has been replaced by a new data set, Meril (https://portal.meril.eu), currently covering 530 RIs. Unfortunately, the more recent data set does not provide the wealth of information on costs, employees, and users available in Riportal and has not been used for the empirical analyses.

[6] The humanities and behavioral sciences exhibits figures that are quite different from the other fields, where the cost of experiments and equipment is structurally higher. Comparisons including this specific field should therefore be interpreted with caution.