Pricing proprietary research projects in large scientific facilities*

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Abstract

Large scientific facilities in all domains of science, are looking at cooperation between science and the industry to alleviate their increasing financial constraints, as proprietary research proposals are charged a price for the time-use of the facility. We argue that present practices to determine those prices are completely *ad hoc* and thus, not based in any economic rationality. This paper presents several alternative pricing mechanisms based on three economic concepts: willingness to pay, social benefits, and opportunity cost. These mechanisms satisfy some desirable properties like publicity, simplicity, and based in well-accepted economic principles.

Keywords: Pricing, large scientific facilities, IPRs, proprietary research proposals, willingness to pay, opportunity cost, social benefits.

JEL Classification: D40, L11, H50

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1 Introduction.

To boost the cooperation between science and the industry, national governments have facilitated the appearance of technological areas around the main cities in Europe and the US. The Life Sciences cluster nearby Paris, the UK Centre for Medical Research and Innovation (UKCMRI) in London, the Parc de recerca biomèdica in Barcelona, the Netherlands' roadmap for large-scale research facilities, the European Spallation Neutron Source (ESS) in Lund, the CERN in Geneva, the European Molecular Biology Laboratory (EMBL) in Heidelberg, and the Euro-BioImaging project (still in its preparatory phase) are representative examples of these initiatives.[1] In all cases, the objective is to generate a dynamic community of researchers and industries to exploit synergies and act as international clusters where to combine science, industry, and business. This objective in turn, is based in the fact that there is a worldwide competition between people, companies, and places. However, while the former two are mobile, the latter is not. Accordingly, companies seeking talent to engage in cooperative R&D projects are willing to locate (at least their R&D units) close to where the talent is (Universities and research centers).

A crucial question in the planning of these infrastructures is the budget needed to build the facility and to operate it once in service. Typically, these budgets rely mostly on public funds. This public funding justifies the fact that scientific users will not be charged any fee. Therefore, if any revenue accrues from the use of the scientific facility must originate from industrial users willing to use the facility as a tool for applied science. Given the aforementioned national budget constraints, there appear big interests in convincing the industry of the synergies that may arise by combining R&D efforts with the researchers using the large scientific facilities, and thus to contribute to their financing.

A relevant aspect to consider in the study of the industrial uses that so far has been neglected is the cost (and pricing) of the service. To evaluate it, it is nec-

[1] At the European level, the networks of research infrastructures funded under FP7 cover all scientific areas: engineering and energy, environment and earth sciences, life sciences, materials sciences, social sciences, mathematics and computer science, and physics and astronomy. See the ESFRI webpage, http://ec.europa.eu/research/infrastructures/index_en.cfm

essary to consider the cost of the use time unit of the installation. In Biological and Medical Sciences the construction, operation and maintenance of research infrastructures are of the order of 100-1000M€ construction costs and 2-150M€ operation costs/research infrastructure/year (BMS RI Group, 2010).[2]

One way to help increase the available funds for large research facilities, still fairly unexplored is the public-private cooperation where a national government would coordinate with potential industrial partners a research agenda and would define the contributions the industry would be willing to make (see National Roadmap Committee for Large-Scale Research Facilities, 2003, p.24). This type of initiatives are often used in the provision of public services where the alignment of interests between the public and private initiatives has proved fruitful. However, aligning the interest in fundamental and applied science might be difficult because from the point of view of the private sector, it represents an investment in an asset not only with uncertain return, but also at a very long term. We will argue that present practices to determine the prices charged on proprietary projects are *ad hoc* and thus, not based in any economic rationality. This paper aims at studying this phenomenon. It first identifies projects not subject to pricing from projects holding the intellectual property rights on the data and outcomes by its promoter. Next, it presents several alternative pricing mechanisms based on three economic concepts: willingness to pay, social benefits, and opportunity cost. These mechanisms satisfy some desirable properties like publicity, simplicity, and based in well-accepted economic principles.

Although practices vary across areas of knowledge, we want to stress a common feature. This is an apparent poor participation of industrial users in the demand of time-use of the scientific facilities. A rough average puts it at around 3% for spallation sources. Together with this, it is estimated that around 10% of time-use for applied research covers preliminary agreements between industries

[2] As a particular example, the UK Centre for Medical Research and Innovation (UKCMRI) aiming at becoming Europe's largest biomedical research facility when it opens in 2015, has a construction budget of 707M€ funded by the UK government and charitable organizations including the Medical Research Council (MRC), Cancer Research UK, the Wellcome Trust and University College London. See http://www.ukcmri.ac.uk/

and research groups to develop projects.

Pricing refers to the mechanisms giving rise to the prices of any commodity (goods and services). Such mechanisms are heavily dependent on the economic characteristics of the environment in which they operate. In other words, a mechanism will differ if for instance an industrial sector is regulated, if there is a market, and so on. Pammolli *et al.* (2002) argue that the scientific and institutional diversity between Europe and the USA is the driver of their different development trajectories in the biomedical industries.

We review in section 2 the present pricing practices, with particular emphasis in neutron facilities. We argue that more often than not, large scientific facilities use "tailor-made" prices that do not respond to any set of criteria. Next, in section 3 we propose a set of criteria able to support rational pricing behavior. Finally, in section 4 we present our proposals of pricing mechanisms to allocate the access to a large scientific research facility.

2 Present pricing practices

There seem to be no systematic, consistent, rational pricing rules for industrial users in (most of) large scientific facilities. Moreover, regarding the users' access to the facilities, each one has its own criteria, processes and legal agreements to be executed before proceeding with the experiments. This introduces artificial barriers to new and nontraditional users. Some of those may well be the industrial users. This element of asymmetric information introduces a distortion in the pricing policies.

In the rest of this section we provide examples of large scientific facilities policies regarding time-use prices for industrial users. These examples illustrate the wide array of possibilities, from posted prices to confidential information.

Posted prices By posted prices we mean that some facilities publish in their webpages the prices of their time-use. However, no information is provided on the criteria supporting them. Accordingly, it is not possible to know whether such prices are linked to the full or average cost of the experiments, or to some other criteria like e.g. historical tradition. Two institutions in this line are the Australian Nuclear Science and Technology Organization (see www.ansto.gov.au/research/bragg_institute/users/requesting_beam_time) and The Svedberg Laboratory (see www.tsl.uu.se/How_to_apply_for_beam_time.html).

Full cost recovery Other institutions announce that projects promoted by industrial researchers are priced according to the full cost of the experiments to be carried out. In this line we find for instance The National Research Council (NRC), whose neutron diffraction facilities at Chalk River (see http://neutron.nrc-cnrc.gc.ca/andi/andibus_e.html) are available for industrial researchers to conduct proprietary materials research, product development and failure analysis. The Applied Neutron Diffraction for Industry (ANDI) activity operates in a fee-for-service mode. Similarly, the Oak Ridge National Laboratory (ORNL) applies full cost recovery for proprietary research (see http://neutrons.ornl.gov/) and the National Synchrotron Light Source (NSLS) prices in this fashion (see www.nsls.bnl.gov/newsroom/publications/manuals/ppm/).

Confidential information The last instance of pricing policy is confidentiality. This means that an industrial researcher interested in submitting a project has to contact the facility and negotiate the price. Examples of facilities following this policy are the European Synchrotron Radiation Facility (ESRF) (see www.esrf.eu/Industry/book-beamtime) and Institut Laue Langevin (ILL) (see www.ill.eu/users/applying-for-beamtime/), ISIS (see www.isis.stfc.ac.uk/apply-for-beamtime/apply-for-beamtime2117.html), the Munich Research Reactor II (FRM-II) (see www.frm2.tum.de/en/), Barcelona Supercomputing Center (BSC) (see www.bsc.es/plantillaA.php?cat_id=5) and the European Molecular Biology Laboratory (EMBL) (see www.embl.org/).

Besides these different pricing policies, and perhaps more worrying, different countries, like The Netherlands and the UK, have set (or are in the process of setting up) National roadmaps for large-scale research facilities (see http://english.minocw.nl/documenten/Dutch%20Roadmap%20Eng.pdf and www.rcuk.ac.uk/research/ Infrastructure/Pages/lfr.aspx) where no reference is made to the pricing of research projects demanding time-use of the facilities submitted by private institutions and the industry aiming at commercial applications. Peculiarly enough, the leaflet with information of the Evry-Corbeil Life Sciences Cluster (see www.sofred.fr/data/editor/documents/opportunites/immobilier/paris-evry-life-sciences-cluster-24032010.pdf) announces "highly competitive CROs/clinical trials costs (20% to 30% lower than in UK or Germany)".

3 A new pricing proposal

One problem found in assessing the allocation and pricing of time-use to commercial projects is the small proportion of time-use devoted to commercial proposals. It is not completely clear whether this small share allocated to commercial uses is endogenously determined by the management of the facilities, or is set *ex-ante*. Be it one way or another, the split of time-use opens a back door to commercial or industrial proprietary projects to be considered as scientific when appearing as a joint proposal of one (or several) private initiatives and one (or several) public research centers (laboratories, universities, ...). From the viewpoint of an industrial user, the main consequence of opting for a commercial or scientific proposal relates to the property rights on the results of the project. Whenever there is public access to the results, the project is considered as scientific and the price of time-use is set to zero. However, commercial and industrial projects holding property rights on the outcomes are priced a positive amount.

The existence of such back door in accessing time-use is thus a problem. No estimation of its importance is available. However, back-of-the-envelope assessment in informal conversations with managers of large facilities lead to a non-negligible amount. Accordingly, *a useful criterion to discriminate those projects to charge a positive price for the use of the time-use, is whether the owner of the project holds property rights over the results of the project, rather than the private or public origin of the proposal submitted to the research facility.* The use of this criterion shifts the focus from the status of the agent leading a project to the policy on property rights. In this way, we will no longer refer to scientific vs. industrial/commercial projects. Instead, we will distinguish projects with public access (to their outcomes) and projects holding property rights (proprietary projects).

Also, given the social benefits of innovations resulting from the development of those projects (increased activity in R&D, improvements in the quality of the industrial structure, enhancement of start-ups and spin-offs, etc), it is reasonable to design a *policy of property rights sharing to incentivize the involvement of the industry in the use of time-use of the large research facilities.*

3.1 Useful concepts

The main concepts that are embodied in our pricing proposal are three: opportunity cost, social benefits, and willingness to pay.

Definition 1 (Opportunity cost)**.** *Opportunity cost is the value of the next best alternative foregone as the result of making a decision.*

The opportunity cost of a decision conveys the choice between desirable, yet mutually exclusive results. Buchanan (2008) describes the opportunity cost as expressing the basic relationship between scarcity and choice. Opportunity costs are not restricted to monetary or financial costs: the real cost of output forgone, lost time, swag, pleasure or any other benefit that provides utility should also be included in the assessment of opportunity costs.

For our purposes, the opportunity cost of a project submitted to a large research facility, is the sum of the material cost and the loss of science of the marginal project (i.e. the top project in the list of turn-down projects).

Definition 2 (Social benefits)**.** *The social benefits of a project are those positive consequences of a research project that indirectly spills over the society where the project is developed.*

Social benefits of an economic activity may have different meanings to different people. In this paper, we refer to the social benefits of research programs submitted to a large scientific facility as those benefits other than the direct economic effects that spread over the society in general. For instance, social benefits will include the impact of R&D activities, on the development of the industrial activity, the local labor market, the potential enhancing in life quality, the improvement of the position of the country in the global scientific world, the increased collaborations across the academic and research community, or the educational improved possibilities for the next generation of researchers. In a nutshell, we regard *social benefits* as the positive impact the development of a particular project that may spill over the society as a whole.

Definition 3 (Willingness to pay)**.** *The willingness to pay (WTP) for a good or a service is the maximum amount of money that an economic agent is ready to pay for that good or service.*

In other words, the WTP is the amount of money that leaves the agent indifferent between consuming the good (or service) and devoting that amount of money to alternative uses. In this sense, we refer to the WTP as an indicator of the value of a good for an individual.

The usual way to directly assess the WTP of the agents is by asking for the maximum amount of money willing to spend in a particular good or service. Implicitly, the agent takes into account all factors (disposable income, tastes, ...) that are relevant to the agent in the provision of the service. Of course, the agent may have incentives to underreport his true willingness to pay.

If there is a market for the good, prices are the reference to assess the WTP (or at least, a lower bound of the WTP) . For non-market goods, one way to assess the WTP is the so-called *contingent valuation method (CVM)*. This method is most often used in evaluating the provision of public goods (e.g. environmental policy issues) or in the public provision of private goods (e.g. health policy issues). The CVM circumvents the absence of markets by presenting consumers with a questionnaire where they are asked to vote for or against upon a described program (the provision of a particular good or service), taking into account that its approval would imply the payment of a tax.

In our context, the way to obtain information of the willingness to pay on the part of the proposer would be to ask in the application form for such information. That is, the proposer would be required to name the price that would be ready to pay should the project satisfy the criteria to be eligible. For the sake of the argument, let us assume the proposer reveals honestly that price. Otherwise, a correction mechanism coping with the incentives for deviating from truth-revealing should be put in place.

3.2 Critical prices for projects holding property rights

To determine the prices of the projects whose promoters hold the property rights of the results, we will use the concepts of *opportunity cost, social benefits*, and *willingness to pay*, as defined above.

It should be clear that no project will be put forward if the price a promoter faces is above its willingness to pay. Formally, the maximum price of a project i, let us denote it p_i^{max}, is the promoter's willingness to pay, $p_i^{max} = WTP_i$.

Also, from the point of view of the society, only projects yielding net benefits are candidates to be acceptable. This means that any project whose social benefits (the only relevant benefits that must be considered given that the private benefits are retained by the promoters) do not offset the cost of developing an alternative project should not be admitted. In other words, the difference between the opportunity cost (OC) of a project and its social benefits (SB) represents the minimum reward the society should obtain from the development of a project. Formally, the minimum price to be charged to a project i, denoted as p_i^{min}, is given by the difference between its opportunity cost and its social benefit, $p_i^{min} = OC_i - SB_i$.

Summarizing, the concepts proposed yields both an upper and a lower bound to the range of feasible prices to be applied to a proprietary project. These are,

$$p_i^{max} = WTP_i \geq p_i \geq OC_i - SB_i = p_i^{min}.$$

If the maximum and minimum prices for a project i are such that $p_i^{max} < p_i^{min}$, then it is optimal not to allocate any time-use to this project as there are better alternatives. On the contrary, it is optimal to allocate time to any project i for which $p_i^{max} > p_i^{min}$ at some price $p \in [p_i^{min}, p_i^{max}]$.

4 A new methodology to allocate time-use

The previous sections report about the *ad hoc* criteria employed by different scientific facilities to determine the prices to be charged to industrial/commercial proprietary projects. Also, the existence of a back door for proprietary projects to appear as scientific, invalidates the distinction between scientific and commercial/industrial projects to determine what projects should be priced.

We propose two alternative pricing mechanisms to determine the price of a proprietary project. One is based in the concept of WTP; the other hinges around the concepts of opportunity cost and social benefits.

The proposal intends to fulfill the following desirable properties:

- *It is public*: The decisions would be based on rules known by all the parties involved (firms, private research centers, public and private researchers, facility staff); in particular, the mechanism should be made public, for example at the facility webpage.

- *It is based in simple well-accepted economic principles*: it uses ideas that have already been discussed and applied in other contexts.

- *It calls for the comparison of* (difficult to evaluate but) *sensible variables*: scientific merit, social benefits, and income (whose value can also be measured by the additional scientific activity it allows to perform). This contrasts with methods based on the imputation of marginal or average cost of the use of the facility, which are not related to the "real" cost of using the infrastructure.

- *It minimizes firms' and private research centers' incentives for strategic behavior*: the identity of the proposer is irrelevant for the outcome of the process. Only keeping property rights matters. This will allow in particular, to have a better picture of the impact of the facility on the industrial sector.

In addition, some variants of the mechanisms are designed to provide countries with incentives to financially participate in the infrastructure as they ensure a *juste* *retour* of countries' investment in terms of time-use.

The mechanisms we propose require the constitution of a team of experts able to evaluate all the proposals. These panels must be able to weight not only the scientific merit of the proposals but also their social benefits and the monetary compensations if needed. While we are aware of the difficulties to form a balanced panel of experts able to do this complex job, the procedure has clear advantages.

First, *it is easier and more transparent* to select a balanced panel of experts than following the prevailing practices (consisting in appointing some person inside the facility, perhaps the director, with the duty of determining or negotiating a "reasonable" price for the time-use allocated to proprietary projects). Second, the repeated and rigorous evaluation of all types of projects, *allows for developing an expertise* by the panel members and building know-how that will improve future evaluation at the large research facilities.

4.1 "Reported prices" mechanism

The first mechanism to determine prices is based on the willingness to pay of the promoters of the proprietary projects. Those promoters should include in the application to the scientific facility, their willingness to pay. That is, they must report how much money they are ready to pay to run the project in the selected facility.

The implementation of this methodology can be done in a centralized or decentralized way. This decision is beyond the scope of this paper.[3] We explain more in detail the centralized version, as the others share many of its characteristics.

4.1.1 Centralized allocation of time-use

In a centralized allocation of time-use, the direction of the large facility designs a panel of experts to rank all the proposals (scientific and proprietary) submitted. The evaluation of scientific projects is based on scientific merit, although the potential social benefits or industrial applications must also be taken into account. The evaluation of proprietary projects is based on the social benefits and the reported price,

[3]However, it will be clear that a decentralized allocation provides higher incentives for the contribution of countries to the budget of the scientific facilities.

although the eventual scientific merit must also be considered.

Given the availability of time-use, the direction of the large facility selects those projects starting at the top until exhausting the available time.

This mechanism to allocate projects is country-independent. This may have two drawbacks. First, countries may have incentives to distort the ranking proposed to maximize the number of projects (or the share of time-use) *at the expense of* other countries. For example, countries may exaggerate the social benefits, the spillovers of a project in the country. Second, some countries will be allocated a lower share of time-use than their share in the ownership of the facility.

4.1.2 Centralized allocation of time-use with *juste-retour* adjustment

This variant of the centralized allocation mechanism aims at eliminating the two problems just described. It adds a criterion of *juste retour* to the previous mechanism. According to this variant, once the panel of experts has produced the ranking of all projects accepted, time-use available would be allocated to countries in proportion to their participation in the budget of the facility. This mechanism eliminates the incentives to alter the ranking because each country only deals with its national projects. No externality on the other countries is generated by reshuffling the set of national projects. It also gives incentives to the countries to participate in the financing of the infrastructure in the first place, as countries know they will obtain a *just retour* from their investment.

4.1.3 Decentralized allocation of time-use

A decentralized mechanism can also be envisaged. In this scenario, the panel of experts ranks separately the proprietary projects and the "public" projects. Then, each country chooses a mix of both types of projects in proportion to its contribution to the budget of the scientific facility. This method allows countries more keen to help industrial development to put more weight on social benefits, while countries more interested in promoting basic research will put more weight in scientific value.

4.2 "Imputed prices" mechanism

We also propose an alternative methodology to rank the projects submitted to a large scientific facility that consists in assessing the opportunity costs of a project and its social benefits besides its scientific merit. As before, this mechanism can be implemented in a centralized or in a decentralized way.

4.2.1 Centralized allocation of time-use

In a parallel fashion as in the previous proposal, by centralized allocation of time-use we refer to the situation where the direction of the large facility designs a panel of experts to rank the "public" projects. Regarding any proprietary project, the panel must evaluate social benefits, the eventual scientific value, and compare such benefits to the "marginal project", that is, the "public" project that cannot be carried out if the proprietary one is chosen. This determines the minimum price to be imputed to each of the proprietary projects. Then, the promoters of the proprietary projects accept or reject the price (and thus the project is maintained in the ranking or eliminated). Finally, the panel of experts produce a final ranking with all the projects.

Given the availability of time-use, the direction of the large facility selects those projects starting at the top until exhausting the available time.

We note that the price to be imputed to the proprietary projects is not necessarily the minimum price as estimated above. The managers of the facility may set a mark-up to this price, so that private firms have a positive contribution to the financing of the infrastructure. They may also apply discounts to attract private partners. It may be a useful policy at the early stages of the functioning of the infrastructure.

4.2.2 Centralized allocation of time-use with *juste-retour* adjustment

The centralized mechanism is subject to the same ill incentives as in the "reported" prices mechanism, so that we consider a variation including a criterion of *juste retour*. Once the panel of experts has produced the full ranking of projects, including the assessment of the prices and the acceptance/rejection decision by promoters of proprietary projects, time-use available is allocated to countries in proportion to their participation in the budget of the facility.

4.2.3 Decentralized allocation of time-use

The decentralized mechanism consists in every country determining the minimum price to be charged to its national proprietary projects. Once the promoters accept or reject the price, the country communicates the panel of experts those projects that remain to be considered, and the panel produces the full ranking. Then, time-use available is allocated to countries in proportion to their participation in the budget of the facility.

4.3 Remarks

Given that scientific projects are not subject to pricing, it is crucial that promoters of proprietary projects do not have incentives to pretend that their projects are "public". Therefore, "public" projects require the signature of a contract including the commitment to publish the outcome of project as soon as possible. This may mean that the data produced must be available within a reasonable time in a public repository at the facility, and/or a commitment to publish an academic paper including the results within a certain period. Teams should be given the right incentives to honor the contract.

The design of a one-dimensional index allowing the panel of experts to rank projects (and in particular to ease comparing scientific and proprietary projects) would be a useful, although not an essential tool.

The "imputed prices" mechanism seems better suited for the early stages of the research facility, when the information of the costs of running the facility and the level of scientific quality of the "public" projects (that is, the "opportunity costs") will be scarce. In a longer horizon, the alternative "reported prices" mechanism seems more convenient as it is simpler to implement.

Countries / project types	“public”	proprietary
Country 1	A_1, B_1, C_1, D_1	a_1
Country 2	A_2, B_2, C_2, D_2	a_2

Table 1: Taxonomy of projects

5 An illustrative example

Consider a large facility whose budget is financed by two countries labeled 1 and 2. Country 1 contributes $2/3$ of the budget and country 2 contributes the remaining $1/3$.

The facility receives ten proposals that can be classified according to the country of origin and by the holding or not, of intellectual property rights on the outcome of the projects. We identify countries with subindices, proprietary projects with low-case letters, and “public” projects with capital letters. Table 1 shows the distribution of projects in those two dimensions.

Finally, to make the example simpler, assume that each project needs the same amount of time-use and that the available time-use allows for selecting six projects.

In this set-up we present the three different scenarios for each pricing mechanism.

5.1 “Reported prices” mechanism

5.1.1 Scenario 1: Pure centralized assignment

A committee of experts selected by the management of the facility provides the following ranking:

$$A_1, B_1, a_2, C_1, D_1, a_1, A_2, B_2, C_2, D_2$$

Given that time-use availability allows to pass 6 projects, the direction of the facility selects the top six projects and discards the bottom four projects. Thus, the allocation is:

- $(A_1, B_1, a_2, C_1, D_1, a_1)$ are accepted.

- (A_2, B_2, C_2, D_2) are left out.

This allocation is country-independent. However, both countries have incentives to try to distort the allocation trying to “place” an extra project at the expense of the other country. Such incentives at the level of the countries are likely to translate in lobbying on the panel of experts.

5.1.2 Scenario 2: Centralized decision with *juste retour*

First, the committee of experts selected by the management of the facility provides the ranking of projects. In the second stage, the facility allocates time-use to the best selected projects, in proportion to countries’ relative financial contributions.

Therefore, the outcome of stage 1 is a ranking as in scenario 1:

$$A_1, B_1, a_2, C_1, D_1, a_1, A_2, B_2, C_2, D_2$$

Next, in stage 2, four projects from country 1 and two projects from country 2 are selected, so that the allocation is

- Country 1: (A_1, B_1, C_1, D_1)
- Country 2: (a_2, A_2)
- Projects $(a_1, B_2 C_2, D_2)$ are left out.

Note that now a country cannot create spillovers on the other country.

5.1.3 Scenario 3: Decentralized assignment

The last scenario we propose is of a different nature. The panel produces two rankings, one of “public” projects and another of proprietary projects. Then, each country selects a number of projects given by its relative financial contribution to the budget of the facility (*juste retour*).

Let us assume that the rankings are

- “public” projects: $(A_1, B_1, C_1, D_1, A_2, B_2, C_2, D_2)$
- proprietary projects: (a_2, a_1)

Imagine that the weights that country 2 assigns to the different criteria used to produce the ranking are the same as those that would be given by the panel of experts, while country 1 weights very heavily the new jobs that project a_1 may generate. Then, the countries ranking may very well be:

- Country 1: (A_1, B_1, a_1, C_1)
- Country 2: (a_2, A_2)
- Projects (D_1, B_2, C_2, D_2) are left out.

5.2 "Imputed prices" mechanism

5.2.1 Scenario 1: Pure centralized assignment

The panel produces a ranking of "public" projects and announces prices of proprietary projects:

- "public" projects: $A_1, B_1, C_1, D_1, A_2, B_2, C_2, D_2$
- prices proprietary projects: (p_{a1}, p_{a2})

Let us assume p_{a2} is accepted and p_{a1} is rejected by the respective promoters. Then, the final ranking of all projects is

$$(A_1, B_1, C_1, D_1, A_2, a_2, B_2, C_2, D_2)$$

so that the allocation is:

- $(A_1, B_1, C_1, D_1, A_2, a_2)$ are accepted.
- (B_2, C_2, D_2) are left out.
- Project a_1 is discarded.

5.2.2 Scenario 2: Centralized decision with *juste retour*

The panel produces a ranking of "public" projects and announces prices of proprietary projects:

- “public” projects: $(A_1, B_1, C_1, D_1, A_2, B_2, C_2, D_2)$
- prices proprietary projects: (p_{a1}, p_{a2})

If p_{a2} is accepted and p_{a1} is rejected, then four projects of country 1 and two projects of country 2 are selected. The allocation is,

- Country 1: (A_1, B_1, C_1, D_1)
- Country 2:(A_2, a_2)
- Projects (B_2, C_2, D_2) are left out.
- Project a_1 is discarded.

5.2.3 Scenario 3: Decentralized assignment

The panel produces a ranking of “public” projects and each country announces prices of its national proprietary projects:

- “public” projects: $(A_1, B_1, C_1, D_1, A_2, B_2, C_2, D_2)$
- prices proprietary projects: $(\tilde{p}_{a1}, \tilde{p}_{a2})$

Assume both prices are accepted. Then, the allocation of projects is

- Country 1: (A_1, B_1, C_1, a_1)
- Country 2:(A_2, a_2)
- Projects (D_1, B_2, C_2, D_2) are left out.

5.3 Extensions

The pricing mechanisms presented represent a simple approach to the problem of pricing proprietary proposals on the data and outcomes. Some extensions to cover more complex scenarios can be put forward.

First, the arguments have been developed in a static framework. It is easy to accommodate the mechanisms proposed to an intertemporal setting including the possibility of a secondary market of time-use. In this market, countries would be able to negotiate prices of time-use across periods. For instance, consider a country that is particularly interested in pushing forward a project that has not been selected. Such country could announce that is willing to buy time-use from another country that may be open to set back one of its selected projects. Alternatively, a country with a selected project of low interest may be interested in announcing its willingness to sell the corresponding time-use.

These intertemporal exchanges can be performed without the need of a secondary market of time-use. However, the presence of the market allows for an efficient allocation of time-use in that "second round" of allocation of projects.

Finally, setting up a framework for reallocation of projects (partially) helps as well to tackle the issue of a systematic unbalance between the financial contribution of a country and the return it gets in terms of share of time-use.

A second extension that can be incorporated in the mechanisms is the possibility that *interested parties* in "public" projects (of high enough scientific value) support them through a financial back up that can be taken into account by the panel of experts to decide the position of these projects in the ranking. For example, a research group may apply for time-use to a neutron facility with a project to study electrode materials allowing for a fast recharge of batteries. Assume this is a scientific project (i.e. the property of the outcome is public). The association of car manufacturers may show interest in that project because its success would help the automobile industry to speed up the development of electric cars and thus, contribute to lower pollution. Therefore, as an association, it may be willing to finance part of the expenses involved.

The proposed mechanisms implicitly assume that countries contributing to the financing of a large scientific facility, are the owners of the facility and the only ones able to use it. However, we can envisage the possibility of third countries not contributing to finance the budget of the facility to submit proposals. This enlarges the type of countries involved in the functioning of the research facility. We could distinguish among countries holding ownership rights of the facility, countries without ownership rights, but that contribute with say, instruments to carry out experiments, and countries that simply would like to make use of the facility. This situation leads to a legal issue of how to define the status of the different possibilities to have access to the scientific facility. But it also opens the discussion to define pricing strategies according to the status of the country where the project originates regarding the facility.

6 Conclusions

This paper aims at introducing some economic principles in the design of pricing rules for the use of time in large scientific facilities by proprietary research projects.

The mechanisms proposed are based on three well-known and accepted economic concepts. These are the opportunity cost of a project, the social benefits of a project, and the willingness to pay of the promoters of a project to have the experiments run.

We present two alternative pricing proposals for proprietary projects satisfying some desirable properties: (i) publicity, (ii) economic foundation, and (iii) simplicity.

The implementation of these mechanisms requires the formation of teams of experts able to evaluate the proposals in three dimensions: scientific merit, social impact, and monetary compensations.

Although our proposal is not without difficulties, we claim that after a (short) period of learning, its advantages will offset the present inefficiencies in the allocation of time-use of the large research facilities. Also, we claim that these mechanisms will encourage a larger participation of proprietary projects, thus contributing to alleviate the financial constraints from public funds.

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