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The Importance of Research Infrastructures for Industry: A national survey

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Abstract: In the developed countries a large share of R&D work is performed in universities, but the real significance of their contribution is larger, since they conduct most of the fundamental research. In this paper we examine one aspect of the academic sector that is visible to most outsiders, a field that requires usually the most resources as well – the research infrastructure. Hungary is currently in the process of forming its own National Infrastructure Roadmap. In the process of it, in 2014 a nation-wide survey was carried out by the National Innovation Office. The study might be a good starting point for making measures and setting up goals for scientific fields. With the identification of research infrastructure usage by industry, the usage of this method might provide a best practice for other countries to undertake similar evaluations for their respective infrastructures.

Keywords: Research Infrastructure; University; Hungary; National Infrastructure Assessment; Survey

Introduction

Business–academia collaborations are nowadays viewed as key factors in bringing R&D results to companies, through the universities "third role" of supporting economic development and the supporting of the national competitiveness (Ambos et al. 2008 ;Etzkowitz 2003; Rasmussen et al. 2006,). These collaborations between industry and universities lead to more intense R&D (Bozeman, 2000) and also to an increase in licensing activities and through them R&D's impact on innovations for the business sector as well (Bonaccorsi et al. 2014). Regardless of the innovation model we examine, be it science-push or the (relatively) new networked model, the core of these theories is the major role of academia in innovation. All models conclude – as is logical – that basic R&D has an impact on innovation, although they differ significantly on how exactly this happens (Caraça et al. 2009; Kline & Rosenberg 1986). We can assume that it is true that basic research has an impact on innovation. In this paper we will examine one aspect of "how" and try to answer the question „"to what extent".

Governments and industry increasingly perceive universities as "a major agent of economic growth": the knowledge factory, as it were, at the center of the economy. In such an economy – one in which ideas and the ability to manipulate them count for more than the traditional factors of production – the university has come to seem an increasingly useful asset. It is not only the nation's R&D laboratory, but also the mechanism through which a country augments its "human capital" the better to compete in the global economy.

In the developed countries a large share of R&D work, about 15 percent, is performed in universities, but the real significance of their contribution is larger, since they conduct most of the fundamental research.

Some authors analyze the relationship between universities and industry on the basis of case studies (for example Meyer-Krahmer & Schmoch 1998); various publications dealing with the problem of how to improve the technology transfer from universities to industry have conducted broad surveys at universities regarding their industrial contacts.

The role of the research infrastructures

In this paper we examine one aspect of the academic sector that is visible to most outsiders, a field that requires usually the most resources as well – the research infrastructure. Without doubt, research infrastructure usage is one of the most logical and apparent usages of academic resources besides research contract with scientists and their institutions. The role of research infrastructure is widely considered as important as basic R&D for innovation, if not more important. It can also be used as an "indicator" for understanding science and technology policy (Jacob & Hallosten 2012). Still, it are only partially studied, and literature on it is limited (Hallonsten & Heinze 2012).

The problem of research infrastructure has a long history from the 1940s till today, from basically giving lots of money to research infrastructures to demanding income from them (Hallonsten & Heinze 2012) – most countries spend huge amounts to upkeep, build or upgrade their research infrastructures in order to provide the necessary equipment for scientists. In some fields of science (e.g., physics) this requires bigger amounts, in other fields it takes less (social sciences). Since spending on R&D for the academic sector comes from governments, it is politically important to make people understand what comes out of this spending. One of the explanatory factors is the usefulness of research infrastructure to industry, thus its direct impact on the economy. Its usefulness and importance is emphasized through various initiatives, such as the ESFRI roadmap (ESFRI 2010). The roadmap aims to identify new research infrastructures of pan-European interest corresponding to the long-term needs of the European research communities, covering all scientific areas, regardless of possible location. Economic importance is not a key factor in selecting the infrastructures for the roadmap – which is fully acceptable, since these infrastructures in almost all cases support basic research, and their industrial relevance is not a priority. Although it is not a factor in selecting the infrastructures to the Roadmap directly, at the evaluation process and the connecting application the research infrastructures (buildings, lab equipment, etc) have to show their relevance to industrial users. The industrial aspect arises mostly from the political side – governments and their citizens wish to see a return on their s money, and not through less-understandable scientific achievements, but in products and technologies which boost industry. This is also boosted by science policy makers, many of whom prefer to view innovation in the spirit of the science-push model, or the linear model at best. Although the lineal model is obsolete by now, and there are many new models trying to take its place – like the multi-channel interactive learning model or the revisited contingent effectiveness model (Bozeman et al. 2015) – its simplicity gives it an advantage and keeps it afloat.

Nevertheless, looking at either models we find that the importance of the academic sector and higher education is undoubted, but still, the public has to be convinced of this fact from time to time. In the case of research infrastructure, one interesting example is that of a major infrastructure under construction, the European Spallation Source (ESS), a key factor in the decision for building ESS in Sweden was "to explain the purpose and usefulness of the facility and the research" (Agrell 2012). However, the linear innovation model leaves a very strong and not very positive mark on public science communication, which can be summed up as "the assumed 'unexplainable' nature of advanced scientific projects and activities" and "the power of catchwords and compelling non-scientific arguments" (Agrell 2012). This sometimes results in decisions, however, which are not always optimal, not only from the scientific but also from the economic side. For instance, certain studies indicate that the decision to build ESS in Sweden was much more of a political decision than one that was based on evidence (Hallonsten 2014). This decision has a component that is interesting from the industry–science cooperation side as well – before the decision the idea of PPP was brought up so that it would boost Swedish industry partners' potential to become partners for the ESS completion, but it was found that their added value would be doubtful. This fact was not taken into consideration at the final decision making either.

The overall situation in big science policy is the logical consequence of science policy change over the times from "justifying investment in basic science by reference only to the utility of basic research" (Elzinga 2012). With the financial restrictions appearing after the Cold War was over, the "old arguments" (or the old communication panels) could no longer be used by scientists, who admitted that "OECD represents the economic and political interests of its members, not the intellectual interests of scientists" (Elzinga 2012). From about the late 1990s it has become a more and more demanding question to see how science contributes to the economy and to society as a whole. Although there is a certain danger to the academic sector in the cooperation with industry, namely the delaying or even the suppression of scientific publications (Banal-Estanol et al. 2015), the expected gain from using these infrastructures for applied research outweighs scientific reasoning.

Nowadays the arguments on science's business orientation include greater cost consciousness, flexibility and efficiency (Barzelay 2001). This results in higher education acting more and more as a private company from a PR view: They use managers to manage the scientific budget and projects, form profit centers or build "brands".

One prominent example in the case of Big Research Infrastructures is their use of acronyms to "code" their infrastructures that are talkative (acronyms that are easy to say and remember) – like ALLEGRO, FAIR, ALICE, CLARIN, VIRGO, CESSDA, PRACE and so on.

Science (and research infrastructures) face the dilemma of how to commercialize their knowledge and show their usefulness to the public (Huzair & Papaioannou, 2012). The usefulness of science is usually shown through open days and various events to the public, but they also have to prove to decision makers that the science they do is important for the economic actors as well.

This importance is hard to measure, however. What would the desirable level of cooperation with the industry be? If we ask a policy maker, then the answer will be likely 'as much as possible'. Still, until now there has been no attempt to define the amount of 'as much as possible' With the usage of a robust dataset we try to define the current and expected amounts of cooperation for each science field's industrial cooperation levels.

National Infrastructure Assessment and Roadmap in Hungary

Hungary is currently in the process of forming its own National Infrastructure Roadmap, which would be a natural addendum to that of ESFRI. In the process of making a Roadmap, in 2014 a nation-wide survey was carried out by the National Innovation Office in the frame of NEKIFUT (National Infrastructure Assessment and Roadmap) project among research infrastructures' owners to gather data on their scientific relevance, demand for improvements and openness for usage for researchers, and so on.

Answers were received from 450, from which a scientific board selected the ones that could be considered as "research infrastructure". This was necessary, since there were some infrastructures that were of scientific importance but not research-oriented (for instance those used for educational purposes only). The structure and size of research infrastructures depends largely on the specificities of the given scientific field, as well as the needs of the research community using it. The entire process was carried out in broad cooperation with the scientific community. The project was led by a Steering Committee (SC), while the three main academic branches (physical and engineering sciences, life sciences, social sciences and humanities) were examined by separate working groups (with a total of 83 members). Overall, the project addressed several thousand researchers.

This process has resulted in numerous valuable outputs, including the development of indispensable tools and methodologies for the governmental research infrastructure development programme; the definition of various infrastructure categories with an internationally unique system for their classification; and the assessment and classification of existing research infrastructures. It has further resulted in IT development for the register itself.

The definition of research infrastructures that was used is the following:

"Those facilities or families of facilities, live and physical material repositories, data repositories, as well as information systems and services which are indispensable for scientific research activities and for the dissemination of the results. Those human resources which are necessary for the professional operation, use and services of research infrastructures are considered to be an integral part of Research Infrastructures."

After the evaluation of the online survey results 361 infrastructures were taken into the Register of Research Infrastructures and their data are currently used to provide background information for the National Roadmap. This number of research infrastructures can be considered as the vast majority of Hungarian research infrastructures, considering that there are 44 Academic (Hungarian Academy of Sciences) Research Institutes including all scientific fields and 12 higher education units (universities and faculties) involved in basic research in Hungary.

International comparison is hardly possible in this matter. One survey on research infrastructure at European level, called MERIL (Mapping European Infrastructure Landscape), which is openly accessible. The MERIL portal gives access to an inventory of openly accessible research infrastructures (RIs) of more-than-national relevance in Europe across all scientific domains, including the humanities and social sciences.

Interestingly, one main goal of MERIL is to "allow policy-makers to assess the state of research infrastructures throughout Europe to pinpoint gaps or duplications and make decisions about where best to direct funding", therefore it can be considered a policy-making tool as well. From 27 countries on European level, it lists 495 operational research infrastructures (among them 26 are Hungarian). If we compare the Hungarian figure to MERIL's figures, the Hungarian database of 328 infrastructures can be considered a robust one – according to our knowledge no other national or international database exists containing this number of research infrastructures.

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Analysis of National Research Infrastructure

The 328 infrastructures were examined and were divided into five branches. Characteristics of the five branches can be seen in Figure 1. The branches were divided in accordance to the Ortelius thesaurus used widely for the classification of scientific branches. (based on data of National Research, Development and Innovation Office of Hungary)

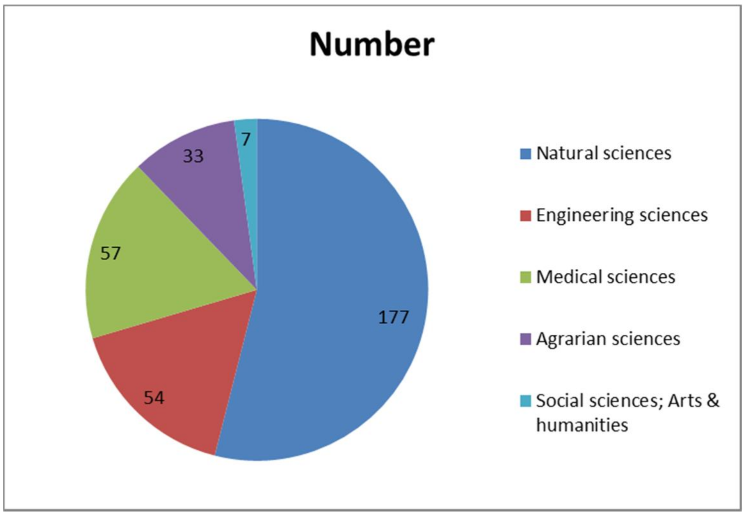

Figure 1. The five branches of the National Research Infrastructure

The online survey was filled out almost unanimously by universities and academic research institutes, which gives us a good overview of research infrastructure division between the various scientific disciplines as well. All research infrastructure were categorized by their main discipline, interdisciplinary was not taken into account, though there are certain fields which operate interdisciplinary. The reason for this is that each infrastructure had to provide its main discipline only, and connections with other disciplines were not obligatory – the survey's answers varied widely depending on the willingness of the answer providers. Since the main discipline was given at each infrastructure we used this data as the main source.

Natural sciences make up more than half of the examined infrastructures, which is not very surprising, since this field uses the most research infrastructure for scientific work. Engineering sciences come second, which has more connection to applied sciences, and still has a relatively high need for a diversity of research infrastructures. Medical sciences and agrarian sciences also have connections to applied research, but their numbers are less than those of engineering sciences. Social Sciences, Arts & Humanities comprise than 10% of the Natural sciences and only 5 % of total research infrastructures.

From these figures it can already be seen that in case of research infrastructures, the biggest need for "stand-alone" infrastructure comes from the natural sciences. As we "shift" towards more and more applied research areas, the demand for a dedicated research infrastructure lessens – medical infrastructure is usually used for actual medical practice as well, agrarian infrastructure is usually used for actual agrarian processes, and infrastructure in engineering is used for production and development besides basic research. The case of Social Sciences, Arts& Humanities is somewhat special, because the low amount of infrastructure means that there are only a few infrastructures (in this case databases) dedicated to these fields, since they require fewer databases, but more comprehensive ones, mostly international ones.

The above analysis provided us with evidence on the characteristics of each disciplinary field. Common sense also tells us that basic research has a bigger infrastructural need in the natural sciences, whose research activities involve basic research more often than those with other possible usages as well. The problem is that until now no attempt has been made (mainly because the lack of data) to assess the current and expected amount of usage of these infrastructures beyond basic research.

This matter can be answered by looking at the cooperation levels of discipline fields with companies. We can assume that the usage of a research infrastructure by companies provides a good indicator for infrastructure usage beyond basic research. Cooperation with companies usually takes the form of applied research or experimental development; only seldom does basic research come into the picture. Applied research and experimental development in optimal cases result in a new or advanced product and thus the cooperation will have an economic impact as well. With the usage of data gathered from the survey we can measure each discipline field's current levels of cooperation. (OECD 2015)

Among the many other data asked from the research infrastructures' owners, we use the following equation to measure the levels of cooperation with industrial partners and provide a suggestion for desired partnership intensity:

$$\mathrm{SCI} = \frac{\mathrm{CU} * \mathrm{TU}}{N}$$

where

SCI = scientific branch cooperation index
CU = company utilization of research infrastructure (%)
TU = total utilization of research infrastructure (%)
N = number of infrastructures in scientific branch.

For instance, research infrastructures in Physics have an average SCI of 7.8 % for 45 infrastructures, containing figures as high as 86 % of total usage and 40 % of company usage, and some infrastructures that are not used by companies at all, though in the same scientific branch.

Other data were considered for use in the determination of the scientific cooperation index, but were later rejected upon testing. For instance, the actual number of researchers was originally thought to provide a good weight number for the infrastructure usage. This figure, however, has no impact on the industrial usage. In most cases industrial users do not directly use the infrastructure, but rather ask for its usage AND the additional knowledge of the scientists, since they simply do not have the skills to use, for instance, a spectrometer. A scientist can cooperate in various projects at any given time, or may not get involved in any project at all, therefore the total number of scientists at a research infrastructure cannot be taken into consideration.

Results

In the calculations the data of the 328 infrastructures were used, divided among disciplines after the data consolidation. This resulted in Figure 2, which shows the results comparing each of the disciplines. The results of the analysis are not surprising in the sense that they support the expectations of industrial partnership levels in the scientific branches. What is striking, though, is the exact level of cooperation, which provides a good basis for any further expectations for industrial usage in certain scientific branches.

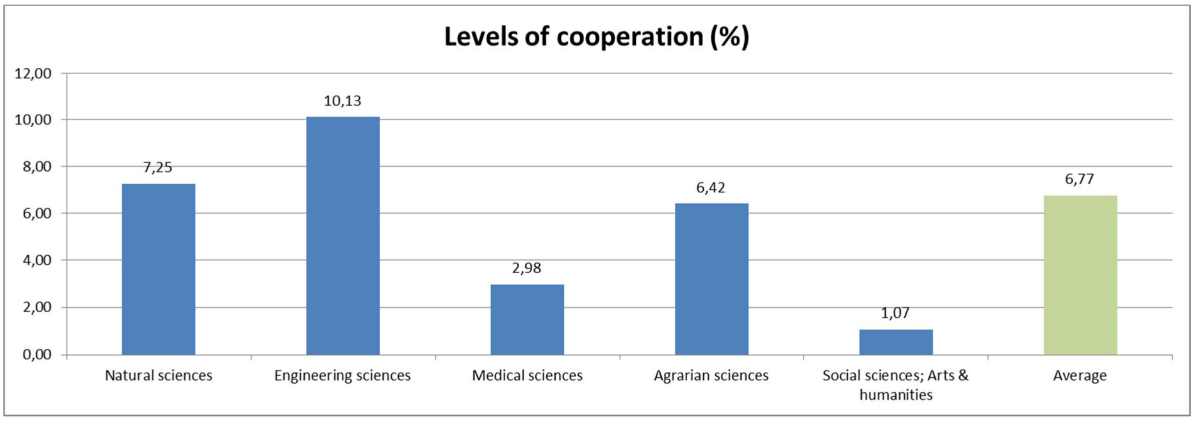

Figure 2. Levels of cooperation

In Figure 2 the calculated average levels of cooperation can be seen. In the first place, it must be noted that the overall percentage of industry and research infrastructure is very low, only a bit more than 6.7 % of the total SCI index. This means that cooperation, with slight differences for the scientific disciplines, is rather an exception than a rule.

Upon taking a closer look at the figures, in the case of natural sciences this amount is 7.25 %, above the average, which can be considered good performance since the majority of the examined research infrastructures came from this branch. With this score natural sciences are the second in cooperation levels with industry; however, this figure also suggests that, despite policy's demand for more and more industrial usage and generating income this way, the cooperation levels are still very low. Since the costs of infrastructure upkeep or improvement are among the highest in the field of natural sciences, it is expected from policy makers that these infrastructures "overperform" – performing better by 7.1 % than the overall (as seen, already very low) average is certainly not the expected figure.

Earth & environment sciences perform very well in this branch, not very surprisingly, the most basic-research-oriented discipline, mathematics, lags behind with only 2.2 %. (Since we weighted the infrastructures with their numbers this latter figure has little influence on the overall score –deducting it, the 7.2 % of usage still remains firmly in place.)

Engineering sciences definitely take the lead in this comparison, with an average of 10.1 %, which is by almost 50 % better than the average. We can assume that these infrastructures are designed (though perhaps not consciously) to be used not only for basic research but for research of applied science questions as well. This results in their closer relationship to industrial partners and their more effective usage. The usage model of engineering infrastructures should be examined in more depth, since this higher level of cooperation could be used to boost industrial usage in other disciplines' infrastructures as well.

The agrarian sciences underperform, though one would expect that the figure should be higher because of its relative close relationship with applied research. It is important to note that this field has two main parts: crops and livestock. These fields perform very differently, with vegetation reaching almost 12 % of SCI, while livestock infrastructure makes up only 2 % of SCI (the number of sample units are almost equal). In Hungary, livestock numbers have decreased in recent years, and it is obvious that not much research has been done in this field. On the other hand, vegetation remains steadily a key factor in Hungary's GDP, and without doubt this can be seen in its R&D involvement – and through it in the research infrastructures' cooperation levels as well.

Medical sciences and social sciences, arts & humanities range around the same modest levels of cooperation, though the reason for this is likely to be different. In the case of medical sciences, while the total utilization of the research infrastructures is high, the company usage is low. This means that on the one hand these infrastructures are mostly used for actual medical practice or, on the other hand, that these infrastructures are dedicated solely to basic research – other infrastructures that are used not only for basic research are used in most cases in applied medicine (mainly through measurements). Therefore, only a small part of the "dedicated" basic research infrastructure can be used for company research, and it can be assumed that companies rather use infrastructures which are closer to applied medicine.

Social sciences, Arts & Humanities sport a very low cooperation figure – in this case the reason is that these disciplines mostly use either databases which are international or database which have a strong national characteristic (e.g. linguistic databases). In the case of company cooperation, these databases are usually not directly used by the companies; the added value of the scientists for the data plays a key role in the collection and evaluation of the gathered data.

Conclusion

In general, research infrastructure usage is quite low – the question remains, compared to what? This study might be a good starting point for making measures and setting up goals for each scientific field. The exact cause of this "underperformance" has yet to be identified. The above figures that are based on a robust dataset lead us to some conclusions to form a realistic level of cooperation demand for the discipline categories.

First, it would be wise to agree on a level of expected company–infrastructure cooperation between the infrastructure's stakeholders. It has been shown, that the "old model" of financing these infrastructures cannot be maintained for various (communication, political) reasons; however, the other extreme, namely the demand for all-industrial usage of infrastructure designed for basic research, can cause more harm than gain. When determining the desired levels of cooperation it always has to be taken into account which discipline is using the infrastructure. Nowadays decision makers put demands based mainly on building or upkeep costs of the infrastructure, which generates unrealistic demands.

Taking the above figures into consideration, it might sound a fair expectation that infrastructures designed primary for basic research should reach at least 5 % company usage as a starting point, while those that can be used more for applied research should reach an industrial usage of 10 %.

Second, in certain disciplines (medical and social sciences, arts and humanities) it would be useful to drop demands for industrial cooperation – the existence of some basic research infrastructure makes it possible to form company cooperation, though not necessary directly linked to the infrastructure itself. Also, we can assume that infrastructures that are used and designed primary for basic research cannot be effectively used for applied research. While licensing is taken into account, the actual company usage of them is not always clear to either of the stakeholders. There is a gap between scientists and company managers, and neither of them realizes the possible potential and/or results of such cooperation.

A possible solution for this issue would be usage of technology transfer officers at each research infrastructure, and, if possible, the "redesigning" of research infrastructures to better serve the identified needs of business users, if needed.

After determining the "desired level" of cooperation, certain innovation methods should be put into practice, much like the forming of technology transfer offices at the universities. Without these, no cooperation strategy can be built and the gap between science and industry will not close. While the survey did not ask whether research infrastructure has dedicated management staff, this is a critical question and might be added to similar surveys. However, we now have data on the services provided by the research infrastructures, which could be a good starting point to opening to the business sector.

This paper might provide a good basis for assessing research infrastructure by providing the desirable level of RI involvement in industry, which is also a level for their likely maximum involvement. With the identification of research infrastructure usage by industry, the usage of this method might provide a best practice for other countries to undertake similar evaluations for their respective infrastructures. We hope the paper helps to shed light on an important part of national innovation systems.

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